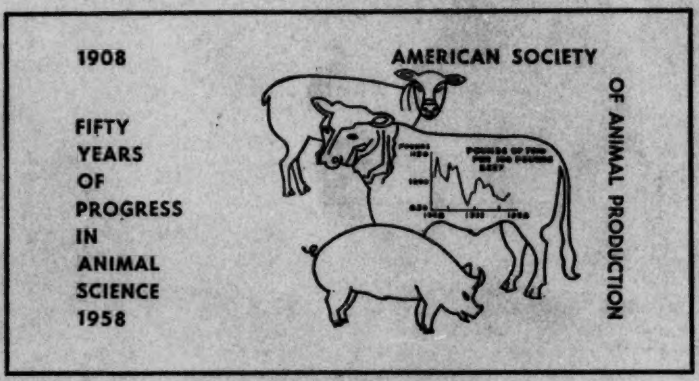
JOURNAL OF ANIMAL SCIENCE

50th Anniversary Issue



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SPECIAL COMMEMORATIVE ISSUE

Journal of

ANIMAL SCIENCE

VOLUME 17 NOVEMBER, 1958

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Executive Committee, American Society of Animal Production, 1958

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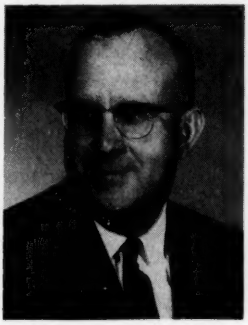

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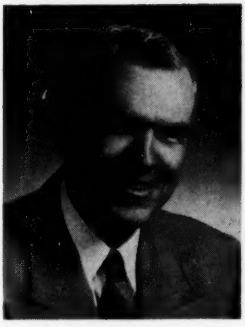

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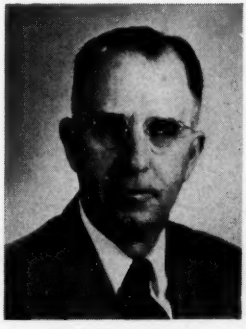

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FOREWORD

THIS special commemorative issue of the JOURNAL OF ANIMAL SCIENCE is published in recognition of the 50th anniversary of the founding of the American Society of Animal Production. It was planned to serve as a brief historical record of progress in the development of knowledge with respect to the breeding and nutrition of our major meat producing farm animals and of the dissemination of that information through our college and extension service systems. The importance of dairy cattle is recognized, but no summary is included because of the comprehensive reviews published by the American Dairy Science Association in 1956 (see *J. Dairy Sci.*, Vol. 39: Huffman, p. 688; Lush, p. 693; Willett, p. 695; Brody, p. 715; Reece, p. 726; Reid, p. 735; Scheidenhelm, p. 789; Davis, p. 795). Together these two volumes give the reader a timely evaluation of the development of animal science during the last half century.

Credit for planning this commemorative issue goes largely to Dr. W. M. Beeson and the Executive Committee of the American Society of Animal Production. A great amount of personal sacrifice and effort was required of the authors in order to complete the review papers on short notice and in time to meet a tight printing schedule. All of the authors responded nobly and deserve a special commendation for their contributions.

The important role of the American Society of Animal Production in the progress of animal science is attested by the fact that practically all of the basic research and education in this broad area has been and continues to be contributed by members of our association.

In the last 50 years, great progress has been made, but these advances were possible only because of the foundation provided by earlier workers. To us, current discoveries may seem all important, but their true significance can be judged only with passing time. It is the accumulation and use of the knowledge of the ages that enables each new generation to advance beyond the last one.

The large contribution of the animal industry to the nutrition, health and well-being of the peoples of the world is generally recognized. The continuing growth and success of this industry depends upon (1) the constant advances of fundamental research; (2) the adequate training of a sufficient number of young men able to become fundamental research scientists, teachers, and competent producers in some phase of animal agriculture; and (3) dissemination of new information as it is discovered so it can be used currently to increase the efficiency of producing and utilizing animal products. While this volume serves to honor those men who have contributed to progress during the past 50 years, greater worth could arise from any stimulus it offers for achievement in the future.

J. K. LOOSLI, Consulting Editor
Commemorative Issue
Animal Husbandry Department
Cornell University
Ithaca, New York

FIFTY YEARS OF GROWTH AND PROGRESS [1]

H. M. Briggs
South Dakota State College, Brookings

NEW and younger members of the American Society of Animal Production may not realize that membership in the Society has more than trebled within the past 15 years. Yet the foundations laid in the first 35 years of the Society have been extremely important in shaping the current activities as well as the advances the American Society of Animal Production has encouraged in the realms of research, resident teaching, and extension. It is well for us to review the past as we plan for the future—and the golden anniversary is an appropriate time to view our Society in retrospect.

H. M. Briggs

Foundation and Early Years

Unquestionably many persons had felt the need of an organization of those interested in livestock investigations before a Society was established. H. R. Smith [2] has written, "In the early days of the International, the men in charge of Animal Husbandry usually accompanied their teams, but of course could take no part in the contest. We would often assemble in the Stock Yards Hotel to discuss the results of our experiments in livestock production and decided then it would be well to have an annual meeting on Friday preceding the opening of the Exposition. There was also at that time a lack of uniformity in preparation of tables giving the results of feeding tests, and it was thought an annual meeting of such an organization would help standardize the presentation of data."

July 28, 1908 is the date an informal conference was held on the Cornell University campus that proved to be the genesis of the American Society of Animal Production. Those who called the meeting were attending a summer school session at that University and were especially interested in the newly developing field of animal nutrition. Thirteen Agricultural Experiment Stations and the Office of Experiment Stations of the United States Department of Agriculture attended the informal session. Typical of meetings, a committee was appointed before adjournment! But this was an instructed committee and the minutes of that meeting tell us they were

[1] Prepared at the request of the Executive Committee of the American Society of Animal Production.
[2] Letter to the author from H. R. Smith, a member of the organization committee and a charter member of the Society.

"to consider the desirability of forming a permanent organization of animal nutrition investigators and, in case it is deemed wise to do so, this committee be given power to call a meeting of animal nutrition investigators at some future time and present plans for permanent organization; that the committee be instructed to make a survey of the field of animal husbandry work and present suggestions for plans of cooperation among various experiment stations." [3]

The committee, which consisted of H. P. Armsby of Pennsylvania, W. H. Jordan of New York, H. J. Waters of Missouri, H. R. Smith of Nebraska, and J. H. Skinner of Indiana, took its assignment seriously. A meeting was called on November 28, 1908, in a room of the Livestock Records Building, Chicago, Illinois, at the time of the International Livestock Exposition.[4] The committee report was presented and it was voted to form an organization to be called The American Society of Animal Nutrition. After discussion and amendment the plan submitted by the committee was adopted as the constitution of the Society. The objectives of the Society were "to improve the quality of investigation in animal nutrition, to promote more systematic and better correlated study of feeding problems and to facilitate personal intercourse between investigators in this field." [5] It is most interesting to note how many of the charter members of the Society developed reputations beyond those they had already made at the time the Society was founded. Most of them still had their most productive years ahead. This may account, at least in part, for the dynamic and progressive approach with which the Society has confronted its problems. The 33 charter members of the Society were:[6]

Allison, H. O., Illinois Agricultural Experiment Station
Armsby, H. P., Pennsylvania State College Institute of Animal Nutrition
Boss, Andrew, Minnesota Agricultural Experiment Station
Burgess, J. M., South Carolina Agricultural Experiment Station
Burns, J. C., Texas Agricultural Experiment Station
Cochel, W. A., Indiana Agricultural Experiment Station
Curtiss, C. F., Iowa Agricultural Experiment Station
Dietrich, William, Illinois Agricultural Experiment Station
Forbes, E. B., Ohio Agricultural Experiment Station
Gaumnitz, D. A., Minnesota Agricultural Experiment Station
Gray, D. T., Alabama Agricultural Experiment Station
Grout, G. P., Minnesota Agricultural Experiment Station
Haecker, T. L., Minnesota Agricultural Experiment Station
Hall, L. D., Illinois Agricultural Experiment Station
Hayward, H., Delaware Agricultural Experiment Station
Jaffa, M. E., California Agricultural Experiment Station
Kennedy, W. J., Iowa Agricultural Experiment Station

[3] The American Society of Animal Nutrition Organization meeting, 1908. Published by the Society, June, 1909.

[4] Letter to the author from Dr. E. B. Forbes, a charter member of the Society.

[5] The American Society of Animal Nutrition Organization meeting, 1908. Published by the Society, June, 1909.

[6] The original published list contained the names of only 32 members but Dr. H. P. Armsby, the first president, later noted the name of C. F. Curtiss, the first vice-president, had been omitted.

Kinzer, R. J., Kansas Agricultural Experiment Station
Lehman, A., Ohio Agricultural Experiment Station
Mumford, F. B., Missouri Agricultural Experiment Station
Mumford, H. W., Illinois Agricultural Experiment Station
Otis, D. H., Wisconsin Agricultural Experiment Station
Riley, E. H., United States Department of Agriculture, Bureau of Animal Industry
Shaw, E. L., United States Department of Agriculture, Bureau of Animal Industry
Shaw, R. S., Michigan Agricultural Experiment Station
Skinner, J. H., Indiana Agricultural Experiment Station
Smith, H. R., Nebraska Agricultural Experiment Station
Smith, P. H., Massachusetts Agricultural Experiment Station
Trowbridge, E. A., Missouri Agricultural Experiment Station
Wade, R. W., Ontario Agricultural Experiment Station (Canada)
Waters, H. J., Missouri Agricultural Experiment Station
Webster, E. H., United States Department of Agriculture, Bureau of Animal Industry
Willard, J. T., Kansas Agricultural Experiment Station

The first "professional papers" presented before the Society were those given in the Exposition Hall at Chicago on November 27 and 29, 1909. At the business meeting it was voted to increase the dues from one dollar to two dollars and that an annual proceedings should be published. During the first years of its life the Society had 100 members on its rolls although the financial records indicate only 78 paid their dues.

A very significant development occurred at the second meeting when a Standing Committee on Experiments was appointed. Years later the word Investigations was used to replace Experiments, but that committee has remained one of the most important ones in the development of the Society. It is felt by many of the early members that it was probably that committee that kept the organization active and alive. The struggling young Society met at the Congress Hotel in Chicago on November 27, 1910. The next fall they convened on November 13 at Columbus, Ohio, and then held an adjourned session at Chicago on December 5.

A Crisis

Perhaps the years of 1912 and 1913 were the two most crucial in the life of the Society. The membership limitation to nutritional research workers in the large animal field was too restrictive because of the small number of active workers in the field at that time. Nevertheless there were two papers that were the result of Society activities.[7]

The annual meeting in 1915 was held in the Pure Bred Livestock Record Building in Chicago on November 30. At that time two very important actions were taken by the Society, the first of which was to change the name to that of The American Society of Animal Production; a second important measure passed was to amend the constitution to allow member-

[7] Bulletin of the National Research Council, Vol. 2, Part 4, No. 12, June, 1921, and Bulletin of the National Research Council, Vol. 7, Part 6, No. 42, February, 1924.

ship to include those interested in teaching and in breeding and management investigations.

While it appeared that the 1912 meeting administered some much needed "medicine" to the ailing Society, the patient was almost "buried" a year later. C. F. Curtis, the Society President for 1913, insisted that the annual meeting be only a social function during the International. However the Vice-President, Dr. E. B. Forbes, a charter member of the Society, believed so firmly that the Society had a more serious professional purpose that he called a "protest" meeting in a room over the sheep barn in the stockyards. At the latter meeting papers on livestock feeding were given by E. B. Forbes, John M. Evvard, F. C. King, and W. A. Cochel. Furthermore, a Committee on Instruction was appointed and it still remains as one of the very active committees of the Society. Personal correspondence with the living charter and early members of the Society reveals that most of them feel that Dr. H. P. Armsby gave the early impetus to the Society but that when Dr. E. B. Forbes refused to succumb to presidential pressure he became the "saviour" of the organization. The real importance of many decisions made by an organization may not become apparent until many years later.

Growth and Development

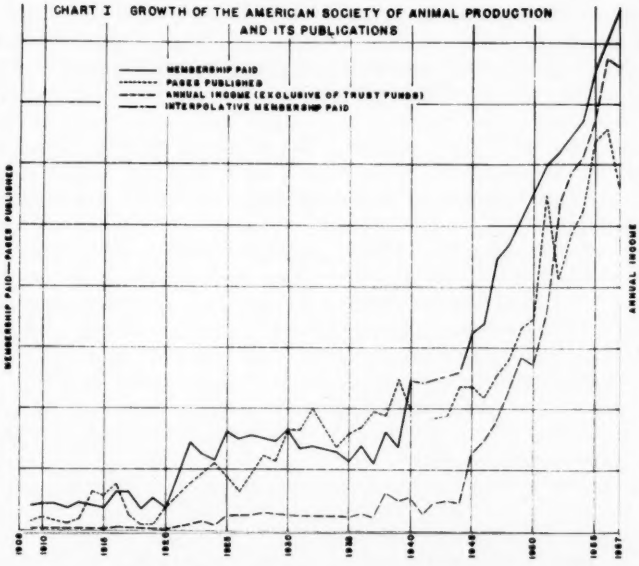
It soon became apparent that the Society was fulfilling a genuine need and would flourish. The constitution was revised in 1915 and only minor amendments were needed until it was again revised in 1932. Ten years later, in 1942, the constitution underwent a thorough revamping (J. Animal Sci. 2:95, 1943) and has remained the operating constitution with but only minor revisions.

Since 1920 the time and meeting place of the Society has been traditional, the time being the Friday and Saturday following Thanksgiving and the place Chicago. This date has been just prior to the International Livestock Exposition. The 1914 meeting was held in Washington, D. C. The next few years found the Society meeting on college and university campuses with the 1915 session at Kansas State College, 1916 at the University of Illinois, 1917 at Iowa State College, 1918 at the University of Wisconsin, and in 1919 the meeting was at Purdue University. After returning to Chicago the meeting sites have been the Sherman Hotel with the exception of 1920 and 1944 when the Society met in the LaSalle and Morrison Hotels, respectively.

The Society dues were raised to $3 in 1926 by vote of the membership. The constitution adopted in 1932 gave the Executive Committee the responsibility of recommending dues to the membership for their approval. The 1942 revision of the constitution empowered the Executive Committee to establish the annual dues. In the interim between constitutional changes the dues varied between $2.50 and $3.00 a year. In 1942 the dues were set

at $3 and were raised to $3.50 in 1945, $4 in 1949, and to $5 in 1952 where they still remain. A registration fee of 50¢ per attendant was assessed at the 1943 and subsequent meetings until 1952 when the registration fee was raised to the current charge of $1.

For many years the Society carried names of persons on its rolls who did not always pay the annual membership dues. Hence membership lists were not accurate indexes of the active or paying members. Chart I indicates the statistical growth of the Society and its activities; the graphic material indicates the number of members who actually paid dues, the



annual income exclusive of grants, and the total number of pages the Society published as proceedings or in the Journal of Animal Science. It is extremely difficult to interpret the membership rolls during World War II so that data for those years have been interpolated as shown. Many former members or prospective new members returned from service and paid back memberships so they could secure issues of the Journal or proceedings published during their absence. There was no publication issued in 1941 in the change from the proceedings to the Journal.

The American Society of Animal Production has never been a dues-paying member of another organization although it has associated with or established liaison with other societies that have mutual interests. Usually the liaison has been through the appointment of a member to serve in a special capacity. Affiliations have been maintained with European

Animal Husbandry Association, Division of Biology and Agriculture of the National Research Council, the Agricultural Research Institute, the American Association for the Advancement of Science, and the Inter-Society Association Council.

Proceedings and the Journal

Each year through 1940 the secretary of the Society prepared a proceedings following the annual meeting. These volumes are written records of the Society and its membership and the papers they contain are indicative of the research progress of their era. In 1940 an Editorial Committee recommended that a journal be established to replace the proceedings and the Society approved. Previously individuals and other committees had contemplated journal publication far more than a decade but nothing definite resulted.

When it was decided to publish a journal an editorial board was appointed and Dr. Ralph W. Phillips was selected as the first editor of the *Journal of Animal Science*. The first volume of the quarterly journal was published in 1942. The editor and the editorial board labored diligently to establish a high quality scientific journal and their achievements were signal because few journals have achieved as much prestige in the first few years of their life. The exemplary editorship of Dr. Phillips has been continued by his successors. Dr. L. E. Casida became editor in 1949 and Dr. J. K. Loosli was appointed associate editor in 1951, and Dr. W. D. Gallup was designated as assistant editor in 1953. Dr. Loosli became editor in 1955 and Dr. Gallup was advanced to associate editor. In 1958 Dr. Gallup was requested to assume the editorship and Dr. A. B. Chapman was appointed associate editor.

The *Journal of Animal Science* was published from its initiation through 1950 by the George Banta Publishing Company of Menasha, Wisconsin, and since that date by the Boyd Publishing Company of Albany, New York. The first volume set the pattern of the Journal which has remained almost unchanged. The first number of the Journal published the abstracts of papers presented at the 1941 meeting and the minutes of the meeting. The February issue, or No. 1 section of each volume, continues to carry a report of the preceding annual meeting. The No. 4 or November issue of each volume carries the abstracts of the papers to be presented at the forthcoming annual meeting and an author index of the volume. Publication of all papers is at the discretion of the editorial board.

As the journal increased in pestige there was an increased demand for the publication. Unquestionably the quality of the journal added to the membership of the Society because each member receives the Journal. In addition there has been a growing demand for subscriptions. In the first year of publication there were 177 subscribers other than members and by 1957 this had increased to 1382 subscriptions. The *Journal of Animal*

Science does not carry advertising and is one of the very few scientific journals that does not receive financial assistance from the sale of space.

At the present time the Society is preparing to publish a monograph that will be of especial interest and value to research workers. It will treat various categories of experimental design, procedure, and data analysis. It is planned that this and other monographs that may be published will be made available to members at a nominal charge.

Meetings and Officers

Prior to 1923 the meetings were conducted entirely as general sessions, but during the next several years subject matter sections were held in addition to a general and business session. The sectioning into subject matter areas was largely based on the class of livestock or general criteria rather than on disciplinary considerations. This approach was changed in 1945 and since that time emphasis has been on subject matter or research approach with less regard given to the class of animal used as the experimental subject. Special symposia have been held from time to time when there was a special demand for such a session. The opening or general session occupied the entire morning of the first day until 1956; that year the general session was shortened and was preceded by subject matter sessions. This practice has made it possible to devote more time to the large number of papers that are available for presentation. Committees have found it impossible, in the time available for the presentation of papers, to place all requests on the program; hence many papers are "read by title." Additional subject matter sections have been added from time to time and presentations have been subjected to a time limit to help facilitate getting as many papers on the program as the limited meeting time would allow. The annual business meeting has customarily been held following the luncheon on the last day of the meeting.

The subject of time, place, and nature of meetings has been discussed and voted upon many times by the Society. At the 1957 meeting a subcommittee was appointed to again study the problem of time and place of meeting and report to the 1958 session.

The elected officers of the Society originally constituted the Executive Committee. The constitution adopted in 1942 stipulated that the Executive Committee would consist of the elected officers, the regional vice-presidents, the retiring president, and the editor of the Journal. The elected officers have been as follows:

	President	Vice-President	Secretary Treasurer
1908	H. P. Armsby	C. F. Curtiss	D. H. Otis
1909	H. P. Armsby	C. F. Curtiss	D. H. Otis
1910	H. P. Armsby	C. F. Curtiss	D. H. Otis
1911	H. P. Armsby	C. F. Curtiss	D. H. Otis
1912	H. J. Waters	C. F. Curtiss	D. H. Otis

	President	Vice-President	Secretary-Treasurer
1913	C. F. Curtiss	E. B. Forbes	D. H. Otis
1914	E. B. Forbes	J. H. Skinner	D. H. Otis
1915	E. B. Forbes	W. H. Cochel	F. B. Morrison
1916	W. A. Cochel	J. M. Evvard	F. B. Morrison
1917	H. S. Grindley	J. M. Evvard	F. B. Morrison
1918	J. M. Evvard	E. A. Trowbridge	E. S. Savage
1919	F. B. Morrison	H. W. Mumford	E. S. Savage
1920	F. B. Morrison	H. W. Mumford	E. S. Savage
1921	W. C. Coffey	E. S. Savage	G. Bohstedt
1922	W. C. Coffey	F. G. King	G. Bohstedt
1923	F. G. King	G. Bohstedt	E. W. Sheets
1924	E. A. Trowbridge	G. Bohstedt	E. W. Sheets
1925	G. Bohstedt	H. P. Rusk	E. W. Sheets
1926	H. P. Rusk	E. S. Good	E. W. Sheets
1927	E. S. Good	E. W. Sheets	James R. Wiley
1928	E. W. Sheets	H. J. Gramlich	James R. Wiley
1929	H. J. Gramlich	James R. Wiley	W. E. Carroll
1930	James R. Wiley	C. W. McCampbell	W. E. Carroll
1931	C. W. McCampbell	George C. Humphrey	W. E. Carroll
1932	J. A. Hill	W. E. Carroll	William J. Loeffel
1933	George C. Humphrey	W. E. Carroll	William J. Loeffel
1934	W. E. Carroll	H. H. Kildee	William J. Loeffel
1935	H. H. Kildee	William J. Loeffel	J. L. Lush
1936	William J. Loeffel	G. A. Brown	J. L. Lush
1937	G. A. Brown	D. W. Williams	J. L. Lush
1938	D. W. Williams	J. L. Lush	R. M. Bethke
1939	J. L. Lush	G. H. Hart	R. M. Bethke
1940	G. H. Hart	W. H. Peters	R. M. Bethke
1941	W. H. Peters	R. M. Bethke	A. D. Weber
1942	R. M. Bethke	L. A. Maynard	A. D. Weber
1943	L. A. Maynard	L. A. Weaver	A. D. Weber
1944	L. A. Weaver	A. D. Weber	W. V. Lambert
1945	A. D. Weber	W. A. Craft	W. V. Lambert and W. G. Kammlade
1946	A. D. Weber	W. A. Craft	W. G. Kammlade
1947	W. A. Craft	Paul Gerlaugh	W. G. Kammlade
1948	Paul Gerlaugh	W. G. Kammlade	H. M. Briggs
1949	W. G. Kammlade	P. S. Shearer	H. M. Briggs
1950	P. S. Shearer	E. W. Crampton	H. M. Briggs
1951	E. W. Crampton	H. M. Briggs	J. I. Miller
1952	H. M. Briggs	M. L. Baker	J. I. Miller
1953	M. L. Baker	A. E. Darlow	J. I. Miller
1954	A. E. Darlow	J. I. Miller	W. M. Beeson
1955	J. I. Miller	L. E. Casida	W. M. Beeson
1956	L. E. Casida	J. C. Miller	W. M. Beeson
1957	J. C. Miller	W. M. Beeson	H. H. Stonaker
1958	W. M. Beeson	W. P. Garrigus	H. H. Stonaker

None of the officers of the Society have received remuneration for the performance of their duties. The increase in membership and the increase in number of papers presented for publication has placed an expanding burden on the secretary and editor. Both of these posts have allowances for secretarial assistance.

A Western Section of the Society was organized at Miles City, Montana, on August 20–24, 1928 to become the first of the sectional societies that function under the auspices of the parent organization. The Southern Section was established later the same year and in 1932 the North Atlantic section held its first formal meeting. The regional sections usually rotate their place of meetings as they frequently meet at the time of other functions; if held independently the site is often a college campus. The sections elect their own officers, and usually charge dues; the dues defray the cost of providing members with proceedings of the meetings.

Honors and Awards

In 1921 the Society elected its first two honor guests and since that date 32 additional members have received this accolade of the Society. The presentation of the portrait of the honor guest to the Saddle and Sirloin Club for inclusion in its world-famous portrait gallery has been a high light of the annual meetings. A Sunday-night banquet in the dining room of the Club usually preceded the unveilings and presentations. Prior to 1955 the Society was afforded the privilege of presenting at least one portrait each year, but currently they must make nominations to the Portrait Committee of the Saddle and Sirloin Club, as do many other organizations; the restricted presentation privilege results from the crowding of the portrait gallery. The members of the Society who have been honor guests are:

1921	H. P. Armsby	1938	F. B. Morrison
	J. H. Sheppherd	1939	Leon J. Cole
1922	H. L. Russell	1940	E. S. Good
1923	C. S. Plumb	1941	E. A. Trowbridge
1924	Eugene Davenport	1942	no honor guest
1925	C. F. Curtiss	1943	H. L. Garrigus
1926	John H. Mohler	1944	F. G. King
1927	Gordon H. True	1945	no meeting held
1928	F. B. Mumford	1946	Henry P. Rush
	H. W. Mumford	1947	G. H. Hart
1929	Andrew Boss	1948	W. H. Peters
1930	E. A. Barnett	1949	J. A. Hill
1931	W. L. Carlyle	1950	C. W. Gay
1932	no honor guest	1951	G. Bohstedt
1933	Robert S. Shaw	1952	A. D. Weber
1934	E. B. Forbes	1953	P. S. Shearer
1935	G. C. Humphrey	1954	L. A. Wearer
1936	W. C. Coffey	1955	no honor guest
1937	W. A. Cochel	1956	Jay L. Lush
		1958	A. E. Darlow

A cash grant of $5,000 was made to the Society in 1946 by Frank B. and Elsie Morrison to establish an annual award to be made to a member who had made outstanding contributions to the livestock industry through his research. In 1948 they increased the grant by an additional amount to

bring the accumulated total to $35,000, and an irrevocable trust was established. If the Society is ever abolished the trust is to pass to its successor. Awards are made from the earnings of the trust. The recipient is presented an engraved remembrance, a certificate, and a cash award; the award was $1000 until 1953 when the amount was increased to $1250, and in 1957 it was raised to $1500. An individual can win the award but once. Recipients of the Morrison Award have been:

1946	J. L. Lush	1952	H. H. Cole
1947	W. L. Robison	1953	Max Kleiber
1948	L. M. Winters	1954	W. D. Gallup
1949	G. Bohstedt	1955	E. W. Crampton
1950	H. H. Mitchell	1956	William E. Peterson
1951	A. G. Hogan	1957	Paul H. Phillips

In 1948 a second cash award was made available to the Society. Since that time the American Feed Manufacturers Association has presented $1000 annually to be used as an award to the member whose published papers during the two preceding years are adjudged to have made the greatest contribution to the field of animal nutrition. Members who have been honored with that award are:

1948	E. W. Crampton	1953	D. V. Catron
1949	J. L. Krider	1954	Wise Burroughs
1950	J. K. Loosli	1955	L. E. Hanson
1951	L. E. Harris	1956	Richard W. Luecke
1952	W. M. Beeson	1957	D. E. Becker

In 1957 the Society voted to establish the designation of Fellow for a limited number of persons who have rendered distinguished service to the field of Animal Husbandry for at least a 25-year period. It has been suggested that selections not exceed one person in the categories of teaching, extension, research, administration and industry; and that not to exceed three additional persons be selected irrespective of category. Appropriate certificates will be presented the Fellows selected. The first such selections will be announced at the 1958 or Golden Anniversary meeting.

In Retrospect

The growth of the American Society of Animal Production can be described by figures and by charts but data do not describe the strength and influence of an organization. Much of that has come from the vision of the membership and from the unrequited activity of those elected as officers and those who served on committees. It is only when an organization is unrelenting in seeking its goals that it continues to grow and serve its members and an industry.

For years the Society's membership was almost entirely limited to college and experiment station staff members, but in recent years there has been an increasing membership from those connected with industry. The paid registration of 1160 at the 1957 meeting is in great contrast to the 245 who paid to register in 1943, the first year such a charge was made. In the intervening years the registration has increased gradually. Here again the influence of the Society cannot be measured alone by numerical criteria—the inspiration that members, particularly those attending their first meetings, may have received could have been the needed impetus to start them on a more fruitful career in research, teaching, extension, or industry.

The growth in membership and influence of the American Society of Animal Production during the past 50 years has been substantial—and that during a half century of the greatest changes that have yet been seen in livestock production, processing and utilization. Keeping its members abreast of these great changes has unquestionably been the Society's greatest contribution.

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FIFTY YEARS OF PROGRESS IN BREEDING BEEF CATTLE

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IN considering progress made over the 50-year life of the Society of Animal Production, it may be best to take a brief look at the situation prevailing in 1908 so far as knowledge regarding the breeding of beef cattle is concerned.

E. J. Warwick

By 1908, the three British breeds of beef cattle had been imported and were well established in the United States. The founders of these breeds and later breeders understood that selection could be expected to be effective and recognized, in a general way, the effects of inbreeding. They realized that inbreeding often resulted in a loss of vigor and reproductive ability, but that it was a powerful tool for improving the predictability of breeding behavior. By 1908, livestock shows were well established in the United States and breeders were relying upon the placings made in the shows for guidance. Breed associations had been established during the quarter century just past and by 1908 were active in promoting the breeds and in keeping pedigree records.

The rediscovery of Mendel's principles had occurred only eight years prior to the founding of the Society and, by 1908, only three strictly scientific papers, all on the inheritance of horns (Bateson and Saunders, 2; and Spillman, 5, 9) are known to have been published on beef cattle. Several general discussions on breeding polled beef cattle (7, 8) and on breeding for performance or adaptability (3, 4, 6) had appeared. Davenport's (10) book discussed certain aspects of breeding as related to beef cattle. Prior to 1908, Galton, Pearson, and their associates had been active in applying statistical methods to the study of heredity, but, so far as is known, none of these early studies had used beef cattle as experimental subjects. The practice, or art, of beef cattle breeding was well advanced by 1908, but was based almost entirely on experience and little, if at all, upon the results of scientific experiments.

Limited experimental work (Wilson and Curtiss, 1) had compared performance of beef and dairy steers and their carcass qualities. Surprisingly,

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the dairy steers gained about as efficiently as the beef type and the percentages of high priced cuts in their carcasses approximately equalled those from beef steers. However, "the carcasses of the dairy breeds lacked in thickness of cut, and the marbling of fat and lean was not equal to that of the others". The percentage of internal fat was excessive in steers of at least some of the dairy types. Experimental work of this type plus many observations by breeders, feeders, and processors seemed to indicate conclusively the superiority of the animals of pure beef breeding over native types then in widespread use in the United States.

Increase in Purebred Beef Cattle Numbers

Since it appeared that the most rapid progress in improving beef cattle would be through the widespread use of purebred sires, the United States Department of Agriculture and State extension personnel embarked soon after 1908 on intensive "better sire campaigns". Numbers of purebred beef cattle registered ranged from about 60,000 to 95,000 in the years from 1908 to 1914. It is probable that there were not enough purebred animals to make it possible for all commercial producers to use purebred sires even had they desired to do so during these early years. Probably largely as a result of the better sires campaigns, numbers of purebred cattle, while greatly influenced by economic booms and depressions, have in general steadily increased. During the period 1953 to 1957, registrations of beef cattle ranged from about 750,000 to 860,000 annually. If we assume that the average beef bull will breed 25 cows annually and has a useful life of three years, we can estimate the number of bulls needed annually to breed the nation's 25,000,000 beef cows at around 325,000 to 350,000. From registration figures it seems probable that purebred sires are now being produced in large enough numbers to be available to all commercial producers who desire to use them. Thus, during the past fifty years it appears that progress, probably exceeding the dreams of the early extension personnel, was made in this area. The interest in purebred sires stimulated a number of experiments on the usefulness of grading up beef cattle during the 30 years following 1908. In most of these experiments, purebred sires of the recognized beef breeds were bred to grade or native females and the performance of their offspring observed, sometimes for only one cross, but more often for two or three generations of grading. The results of these experiments (15, 18, 20, 21, 22, 32) in all cases showed increased selling prices for the progeny of purebred sires and in most cases indicated a production efficiency for them equal to or better than that of native animals. There were exceptions to the latter, but overall the results indicated the better sires compaigns were on sound ground from an economic standpoint. The success of these campaigns must therefore stand as a milestone in any history of the progress made in beef cattle during the life of the American Society of Animal Production.

Breeding Methods Used by Breeders

Following the development by Wright (11) of workable methods of estimating inbreeding and relationship coefficients a number of studies were made in beef cattle to evaluate on a more precise basis than had previously been possible, the procedures which breeders had used in forming and maintaining the various breeds. McPhee and Wright (14) found that rather intensive inbreeding had occurred during the formative period of the Beef Shorthorn, and that breeders were continuing to inbreed at a somewhat faster rate than would be necessitated by population size. By 1920 the average animal of the breed had an inbreeding coefficient of approximately 26%. Willham (29) found an average inbreeding coefficient of 8.1% in Herefords in 1930 and estimated that only 4.6% of this would have occurred due to limitations of population size. Stonaker (35) found an average inbreeding coefficient of about 11% in Aberdeen-Angus breed as of 1939. In all three breeds a major part of the inbreeding had occurred during the formative stages of the breed with increases averaging well under 1% per generation during the latter years of the studies. Rhoad (48) found that inbreeding had occurred during the formative years of the Santa Gertrudis breed to an extent comparable to its use in the older breeds.

Research on Evaluating and Improving Beef Cattle Performance

For much of the half century under consideration, beef cattle breeding research was a neglected field. Black (28) reported in 1936 on a questionnaire seeking information on birth weights, gains, efficiency of feed utilization, and quality of the animal and carcass, which had been sent to each of the 48 State Agricultural Experiment Stations. Eighteen Stations responded and of these, only five reported having any definite breeding projects with cattle. Some of these included merely the maintenance of a herd for instructing college classes in Animal Husbandry, with no intention of collecting data on breeding problems. About 1930, the U. S. Department of Agriculture had initiated research work aimed at developing methods of measuring performance of beef cattle. In addition to the U. S. Department of Agriculture's work, several State experiment stations, including California, Minnesota, Arkansas, New Mexico, Colorado, Texas, Montana, Georgia and perhaps a few others, were doing some performance testing work prior to the end of World War II.

In 1946, Congress passed the Research and Marketing Act, which provided for cooperative regional projects on agricultural problems which were too broad for a single station to undertake alone, and which did have important application and significance over a large territory. Since the problems inherent in beef cattle breeding fit this category, three regional beef cattle breeding projects were organized and were functioning by 1948.

In the three regional projects, 35 State experiment stations and the Territory of Hawaii have active projects and six Federal stations, each operated cooperatively with the State where located, contribute to the program. Much of the research information now available in the field of beef cattle breeding has emanated from these projects. Early work at Beltsville (24) and at the Minnesota Station (26) showed definitely that cattle varied in their ability to grow, in the efficiency of gains made, and in the quality of final product as measured by selling price. On the presumption that these observed differences were, at least in part, hereditary, preliminary proposals on record of performance procedures for beef cattle were made. The Minnesota proposal called for measuring daily gain of a calf from birth to approximately a year of age, at which time he was to be scored for body type, the score converted to a scale with the same mean as observed for average daily gain, and a final index arrived at by multiplying average daily gain x score. Sheets (24) proposed a somewhat more complicated plan in which calves were kept in drylot and allowed to nurse twice daily. Weights taken before and after nursing were used for estimating milk production of the dam each 28 days. Calves were allowed access to creeps and weaned on the 252nd day of age. The next day they were started on a standard fattening ration and fed individually under standard conditions until they reached 900 lb. at which time they were slaughtered. Detailed carcass data were to be obtained. Information on test animals was to be used as a progeny test to evaluate the breeding stock from which they came. The plan envisaged final evaluation on the basis of a factor for production efficiency (expressed in terms of number of pounds of cold dressed carcass produced per 100 lb. of total digestible nutrients consumed) and a factor reflecting carcass quality.

Knapp and Nordskog (40, 41) using data from the U. S. Range Livestock Experiment Station, Miles City, Montana, presented the first estimates known to have been made of the heritability of quantitative traits in beef cattle. They reported small to moderate estimates for birth and weaning weights, and extremely high heritabilities for gains during a postweaning feedlot test, for efficiency of gain during the test, and for final weight at the end of test. Heritabilities were above 50% for weaning conformation score, slaughter steer grade, carcass grade, and area of eye muscle. Several of these heritability estimates approached 100%, thus appearing to be unrealistically large. The writers postulated that the extremely high heritabilities were possibly due either to 1) sampling error due to the relatively small number of observations, or 2) the possibility that some environmental effects had been confused with hereditary effects. The lower fiducial limits appeared to be sufficiently high, however, to indicate that selection would be expected to be effective in populations of the type sampled.

Since 1946, numerous studies of the heritability of economic traits in beef cattle have been made. Table 1 is an attempt to summarize studies known to have been reported to date.

TABLE 1. HERITABILITY ESTIMATES FOR BEEF CATTLE CHARACTERS

Character	No. of estimates	Av. of estimates	Range of estimates	References[a]
		%	%	
Calving interval	3	8	0–15	69, 116, 137
Birth weight	15	41	11–100	40, 50, 52, 74, 84, 89, 90, 91, 96, 108
Weaning weight	26	30	—13–100	40, 50, 52, 74, 76, 86, 89, 90, 91, 96, 103, 108, 109, 125, 131, 133
Cow maternal ability	2	40	19–60	74, 134
Post weaning feedlot gain	13[b]	45	19–70	40, 52, 57, 84, 95, 96, 97, 108, 123, 125, 129, 130
Post weaning pasture gain	6	30	9–43	89, 90, 91, 123, 130
Efficiency of feedlot gain	4[b]	39	3–75	40, 84, 96
Carcass traits:				
Dressing percent	2	71	69–73	84, 96
Carcass grade	5	34	—30–84	41, 52, 84, 96, 108
Rib eye area	3	69	69–72	41, 52, 96
Tenderness	2	61	41–81	117, 121
Conformation grades:				
Weaning	16	26	0–53	41, 52, 57, 62, 89, 90, 91, 108, 110
Slaughter	5	39	—13–63	41, 52, 84, 96, 125
Cancer eye susceptibility	2	32	23–41	99, 111

[a] Numbers refer to numbers of references in Literature Cited.
[b] A few unreasonably high or low estimates omitted.

Two studies (123, 129) have involved the mating of selected high and low gaining bulls to equivalent groups of cows with the progeny being fed out under standardized conditions and their performance compared with that of their sires. Both tests indicate conclusively that rate of gain is an hereditary character and indicate heritability figures in the neighborhood of 40%.

The results of Winters and McMahon (26) and of Knapp and Baker (37) indicated that rate and efficiency of gain were rather highly correlated in beef cattle with rate of gain accounting for from 70 to 80% of the total variation in efficiency of gain, provided the animals under test were fed through a weight-constant period. This generalization has been confirmed by a number of workers. As Guilbert and Gregory (36) pointed out, the relationship between rate and efficiency of gain must also take into account the composition of the carcass produced if it is to be fully useful. Within the range of sizes ordinarily encountered in cattle of conventional size and type, however, it appears that the relationship is high enough for practical use.

With the recognition of the importance of cow productivity as measured by the weight and quality of calves at weaning time, interest in developing

information on pre-weaning performance also developed. Koger and Knox (44) found the performance of brood cows as measured by weight and score of their calves was a repeatable characteristic and that the average performance of a herd could be improved by culling out those cows with poor records on the basis of their first, or first and second, calves. Their generalizations have been confirmed in many other studies (see 67 and 108 for references), and it appears that, under most conditions, the repeatability of cow performance is in the neighborhood of .4 to .5.

Much research effort (see 88 for references to earlier work) has been put into studying the effects of environmental factors, including sex, age of dam, season of calving, etc., on performance of calves. It is apparent that adjustments are needed if maximum selection accuracy is to be attained, but it also appears that the magnitude of adjustment factors needed varies from herd to herd.

Information of the foregoing types, namely 1) that beef cattle differ in their inherent productivity, 2) that these differences are fairly high in heritability, 3) that rate and efficiency of gain are rather highly correlated and 4) that brood cow performance is important to the total economy of beef production and that it is a repeatable trait, have led, during the past ten years, to the formation of performance testing programs throughout the United States. These programs differ in detail but most provide for evaluating weight and conformation of calves at weaning and again at yearling age after a period in feedlot or on pasture. Extension departments in 33 States now have organized programs. Seven of these States have breeder organizations sponsoring the testing program and six State associations are affiliated with a national association founded in 1955 with headquarters in Canyon, Texas. In 1957 there were about 1440 herds involved in these programs throughout the United States.

Organized performance testing programs have as yet touched only a small percentage of the nation's seedstock herds, but they have attracted much attention during the past few years and it is impossible to evaluate the impact which they may have had and are having on the beef cattle industry.

An important objective of beef cattle breeding research is the estimation of genetic interrelationships of important traits in order that selection indices permitting maximum progress may be constructed. Since large bodies of data are required for precise estimates, only a few reports on genetic correlations have as yet appeared. Koch and Clark (91) using data from the U. S. Range Livestock Experiment Station, Miles City, Montana, observed a negative relationship between maternal abilities and post weaning gaining ability. On the basis of these data they stressed the necessity of raising potential breeding animals on their mothers to avoid indirect selection against maternal ability. Urick *et al.* (130) studied gains of steers through three seasons including a winter feeding period, grazing for a summer, and a second winter feeding period. Genetic correlations were

positive for all periods thus making it probable that selection in any one period would result in some genetic gain in others but that maximum gain would be attained if selections were made in the period and nutritional regime under which the stock would be used in commercial production. Knapp and Clark (43) observed positive genetic correlations between gains in consecutive 84-day periods of a 252-day feeding period. They concluded, however, that maximum expression of genetic differences occurred late in the feeding period. The same workers (57) observed positive genetic but negative environmental correlations between weaning score and subsequent feed lot gains. Carter and Kincaid (115) and Blackwell *et al.* (113) have studied genetic relationships among grade and gains at various periods.

Comparisons of Breeding Systems

Research programs have had as one of their principal objectives the evaluation of different breeding programs and systems. Crossbreeding work involving Brahma x British crosses, will be discussed in a later section. Two crossbreeding experiments with British breeds (47, 55) gave conflicting results. The first work at Miles City, Montana, indicated crossbreeding might result in enough hybrid vigor to make it a profitable enterprise, while Gerlaugh and coworkers at Ohio found only a little advantage for crossbreds over the average of the two parental breeds tested. The Ohio work, however, did not include evaluations of the performance of crossbred cows as brood cows. Additional crossbreeding experiments with British type cattle are underway at the present time.

Several experiments on inbreeding beef cattle are underway, but due to their longtime nature, few conclusive results are available. From preliminary data, it appears (58, 70, 79) that in beef cattle as in other species, inbreeding results in an average depression of performance which is particularly serious in reproduction. Preliminary results of crossing inbred lines at the Colorado (98, 132) and Miles City Stations (127) have given promising results as have topcross results (107). It is, however, far too early to more than hazard a guess as to whether performance of crossline and topcross animals will be as good as could be expected from lines in which mass selection had been practiced for an equivalent time. Even if the crossline and topcross performance should be superior to that of outbred animals, it is not known how much better it would have to be in order to repay the high cost of developing inbreds.

Beef Cattle Type

The question of type in beef cattle has been a live one throughout the half century covered by this review. The trend during much of the period was toward the development of more compact, short-legged types of beef cattle within the British breeds. Objective information is lacking on the extent of these changes but most close observers (for example, Darlow, 49)

feel that beef cattle have developed much smoother types that finish at lighter weights. Some breeders believe that these changes resulted in decreases in size, but throughout most of the period this type has been preferred in show rings and by many commercial feeders.

Hultz and Wheeler (16) divided high-grade two-year-old steers into low-set, medium and rangy groups on the basis of body measurements and found that the low-set animals subsequently gained slightly faster and more economically than the other groups. Lush (23) found that correlations between measurements and subsequent performance were small but statistically significant in several cases with a tendency for animals long in body, tall at the withers, small in flank girth, large in paunch girth and with narrow loins to gain fast while animals with narrow heads, shallow chests, wide loins, large flank girth, small paunch girth, and short height at hips tended to have high dressing percentages and high carcass value. It must be emphasized that all these relationships were low and Lush summarized his study by saying, "Steers of many types will gain well and steers which gain the same way may be of many different shapes. The same is true of dressing percent and meat values, although future dressing percent and future live meat value are slightly more closely correlated with conformation than future gain is".

In an 11-year Montana experiment (34), foundation herds of grade Herefords were divided into groups of large and small types and bred to bulls of corresponding types—as were their daughters when they reached reproductive age. Replacement heifers from the large type were heavier at all ages, and large type steer calves averaged heavier into the feedlot. Feedlot margins of profit average slightly but not significantly greater for the larger type steers.

New Mexico studies (42) in which feeder steers were classified as compact, medium and rangy by visual methods at the time they went into the feedlot, indicated that the rangy steers were somewhat heavier initially, that they gained somewhat more rapidly on test, and that they had a higher dressing percentage than either of the other two types. Carcass grades of the three types were comparable. These workers interpreted their results as indicating that type in itself, directly affected only size and dressing percentage. The apparent effect on gain was probably due to differences in size. They pointed out that it would probably be more difficult to obtain rapid-gaining steers of a compact type than with animals exhibiting greater ranginess.

The New Mexico Station also conducted tests (77, 124) in which heifers were divided by visual appraisal into groups selected in one group for compactness and grade and in the other for weight for age at the time they entered the breeding herd. Each group was bred to bulls of the same type as the cows. Over a period of ten years, cows of each group raising calves raised approximately the same live weight of calf per 1000 lb. live weight of cow. Cows of the second group with an average calf crop of 93.8%

were superior in reproductive performance to the compact cows which averaged only 81.6%. Knox has interpreted these results as indicating that cows with good weight for age as heifers were better adapted to range conditions in New Mexico and that their higher percentage calf crop was a reflection of their better adaptability to the conditions under which they were raised.

The foregoing experiments were conducted on cattle selected from the two ends of the distribution in herds where a continuous type of variation was evident. In the late 1930's and early 1940's, hereditary types known as "Compacts" in Shorthorns, and "Comprests" in Herefords, appeared in which the variation was a discontinuous type. When they appeared on the scene,[3] it became evident that objective evidence was needed on the question of their productivity. Washburn *et al.* (46) found that Compact and conventional Shorthorn steers did not differ appreciably with respect to food capacity per unit of body weight or the ability to digest nutrients in the ration. Conventional type animals exhibited a somewhat greater ability than Compacts to utilize digested dry matter during growth. The Compacts reached a market grade of Choice 70 days earlier than did the conventional animals. The conventional type animals, however, were found to carry more fat at slaughter, so there is a possibility that the Compact animals gave the appearance of being finished to a greater degree than was in fact the case.

The American Hereford Association took a highly commendable approach to the problem by supporting type research at four experiment stations. Work at the Ohio, Kansas, and Oklahoma Experiment Stations (summarized by Weber, 59) in which steers of three types were fed under three regimes, i.e., 1) immediate full feeding as calves, 2) deferred feeding as yearlings, and 3) grass fattening as two-year-olds, showed relatively small differences in economy of production and in market acceptability of carcasses. The medium and large type steers gained faster than those of small types. The carcasses from the large type animals graded slightly less than those from the other two types. Weber concluded that the medium type steers combined the growing ability of large animals and the carcass acceptability of the small type to a considerable degree and recommended that breeders select animals of medium size and type.

Research at the Colorado and Oklahoma Experiment Stations, (64, 65, 72) compared the productivity of Comprest cow herds and herds of conventional or large type. In the Colorado experiments, the weaning weights of Comprest calves and of calves from Comprest cows were less than those of conventional type. When fed individually in drylot to a low Choice

[3] Their impact on the beef cattle industry is forcefully pointed out by the following written by the late Rank C. Forbes in the October, 1946, issue of the *Breeder's Gazette:* "Then out of nowhere came "Comprest" Herefords—and they really were a sight to behold. Although of popular bloodlines, the new type differed from anything thereto seen. Extremely lowset on ideal underpinning with smooth, bulging quarters and deep wide middles to match, with short necks and beautiful heads, the calves and yearlings were sensational".

slaughter grade, Comprest type steers gained as efficiently per unit of feed eaten as did conventional type steers. The conventional type steers ate more, gained more per day, and reached the slaughter grade of low Choice weighing about 20% more than Comprest steers. Comprest steers reached the low Choice slaughter grade only seven days sooner than conventional animals. Carcasses from the Comprest steers were smaller and their dressing percentage averaged about 1% lower. Percentages of the major cuts in the carcasses and composition of the 9–10–11 rib cuts were essentially similar for the two types.

In the cow herds, the amount of feed necessary to maintain weight was approximately in proportion to live weight. In the Oklahoma work, average weaning weights and feedlot gains of the Comprest calves were smaller than those of the large type animals with which they were compared. There was a tendency for the large type animals to gain more efficiently in the feedlot.

In both experiments, net reproductive rates of the Comprest type animals, were lower, due in large part to the high incidence of dwarfism encountered. This will be discussed in a subsequent section.

Probably partially as a result of these experiments, indicating no important advantages for Comprest type cattle and several very distinct disadvantages, and partially as a result of observations by cattlemen confirming the experimental results, they rapidly lost their popularity and have faded from the American scene.

There is a widespread feeling among both cattlemen and research workers that the trend during the 30's and 40's toward ultra-thick, deep type cattle, probably accomplished largely by selection for shortness of leg and body with a resultant reduction in body mass, went too far. As a result there is now a trend toward more size and ranginess but efforts are being made to retain thickness of body. The relationship of conformation to carcass quality is of primary importance in determining what type of cattle may be most desirable. The fact that these two characteristics may not be as closely related as had long been assumed has been implied in some of the experimental results quoted above. Reviews presented at a symposium at the 1956 American Society of Animal Production meeting (114, 124) indicate definitely that many old beliefs have little or no substantiation in fact and pinpoint the need for additional objective information in this general field. Woodward *et al.* (80) studied a number of production factors in relation to carcass traits and found that long bodied steers had as desirable carcasses as short bodied steers. In general, desirable preslaughter and postslaughter characters were positively correlated.

Use of Body Measurements for Evaluating Beef Cattle

Many attempts have been made to use body measurements for predicting performance (16, 23, 30); as indicators of conformation, slaughter, or

carcass grades (25, 31, 54, 87, 101); and for estimating weights of wholesale cuts (66, 75). Many of these studies have shown statistically significant relationships but these have usually been of a low order with low predictive value. The statement of Lush (17) that "In the geometrical sense the animal body is of such a complicated shape that any one or a few measurements could approximate a description of it in only the crudest way" has perhaps not been taken seriously enough.

New Breeds of Beef Cattle Developed

Three British breeds of beef cattle—the Hereford, Angus and Shorthorn —were the only ones present in any appreciable numbers in 1908. They still dominate beef production in the United States. These breeds and their polled varieties, in the case of Herefords and Shorthorns, accounted for about 95.3% of all beef cattle registrations in 1957. However, these breeds have not had and do not now have an uncontested monopoly. Two Scottish breeds, the Galloway and the Highland have been present in small numbers in the United States for many years. Occasional individuals of the humped Zebu type cattle of India had been imported into the United States as far back as 1849. No importation in numbers sufficient to have any appreciable impact on the cattle business, however, had been made until 1906, when an importation was made by the A. H. Pierce and T. M. Pierce estate of Texas. The American Brahman Association was organized in 1924 and has grown so that during recent years it has registered from 15,000 to 25,000 animals annually. The American Brahman represents an amalgamation of several Indian breeds and thus merits the designation as a new and distinct breed. Experimental work during the past 30 years shows that calves with some Brahman blood grow faster to weaning and they grow faster as yearling and two-year-old steers under summer grazing conditions than do animals of British types (see 122 and 126 for references to earlier work). Crossbred or quarterbred Brahman cows in most trials have weaned heavier calves than British type cows under Southern feed and climatic conditions. In some experiments, Brahman crossbreds have performed as well in the feedlot during winter months as have animals of British types, while in other cases, their gains and efficiency of feed utilization have been somewhat inferior. When killed at weaning as slaughter calves, the carcasses of calves with Brahman blood have usually graded about on a par with those of British types. However, at yearling and older ages there has been a tendency for them to grade somewhat lower by U. S. grade standards. Limited research has given conflicting results on the question of whether the eating quality of the meat from Brahman crossbreds is equal to that of British types. In one experiment the average tenderness was approximately equal (117) while other experiments have indicated some tendency for meat from the Brahman crossbreds to be less tender (27, 82).

Observation and some experimental evidence indicated that while the Brahman contributed factors which made their crosses superior to cattle of British types for beef production under Southern conditions, it was also true that the crossbreds exceeded the Brahman in productivity (61). Observations of this type led to several attempts to produce new breeds based on a mixture of Brahman and British blood. The first and most numerous of these new breeds is the Santa Gertrudis, developed by the King Ranch of Texas, starting about 1918 (48). The Santa Gertrudis was founded with animals of about 3/8 Brahman and 5/8 Shorthorn background and has the distinction of being the first breed of cattle—beef or dairy—to be developed wholly in the United States. In 1951 Santa Gertrudis breeders formed an association, the Santa Gertrudis Breeders International. Since many breeders of Santa Gertrudis cattle operate multiple sire herds, making individual pedigree certification difficult or impossible, the association to date has not been registering cattle in the traditional sense but has been classifying foundation animals. More than 77,000 animals have been classified to date.

Brangus cattle are based upon a Brahma-Angus crossbred foundation and possess 3/8ths Brahman blood and 5/8ths Angus blood. They are registered with the American Brangus Breeders Association, which was founded in 1949. In 1957, 3,500 animals of this strain were registered.

The Lasaters of Falfurrias, Texas, and Matheson, Colorado, starting in 1908 developed the Beefmaster strain of cattle from foundations of Brahman, Shorthorn and Hereford. There is no Beefmaster association, but the term "Lasater Beefmaster" is a trademark which has been copyrighted through the United States Patent Office.

During recent years, a French breed the Charollais, has been imported in small numbers through Mexico. The registration association is operating with an open herd book, registering animals with five top crosses. The registrations of 546 in 1957 indicate that the breed is still relatively small, but it has attracted much attention in recent years and limited experimental data suggest that Charollais animals and their crosses may possess the potential for rapid growth (81, 119). The Charbray, developed upon a Brahman-Charollais foundation, has attracted considerable interest in recent years in the Gulf Coast area, but as yet, is being produced in relatively small numbers. Registrations in 1957 totaled 1,357 head.

One of the outstanding trends of the past 50 years has been the increase in popularity of polled strains of the Hereford and Shorthorn breeds which were few in numbers in 1908 but which now account for about 22 and 30% of all registrations, respectively, in the two breeds. The polled strains or breeds were developed from polled "sports" or mutants occurring in the parent breeds.

Research in Breeding Beef Cattle for Hot Climates

Most of the activities in developing new breeds have been in the South and have had as their basic purpose the development of types which would

out-perform British types under the climatic conditions prevailing in that region.

Rhoad (33, 38) described a method for evaluating heat tolerance in beef cattle which involved measuring the ability to maintain a normal rectal temperature while standing unprotected in direct sun on days with high atmospheric temperatures. He demonstrated that Brahman cattle and Brahman-Angus crosses were distinctly superior to Angus in this regard. Cartwright (83) made observations on rectal temperatures in a heat chamber at 105° F. and on respiration rate in the sun under summer pasture conditions and found that Brahmans and their crosses maintained more nearly normal reactions than did Herefords or Red Polls.

Ragsdale *et al.* (128) compared the growth of Shorthorn, Brahman, and Santa Gertrudis heifers when maintained continuously at temperatures of 50° F. and 80° F., and in an open shed at Columbia, Missouri. The Shorthorns exhibited inferior growth at 80° F.

Attempts to use physiological responses to predict performing ability of cattle under hot environmental conditions have not met with much success. Vernon *et al.* (138) found only low and insignificant relationships between Rhoad's coefficient and liveweight gains of either cows or their calves in Brahman-Angus or Africander-Angus crossbred populations being bred *inter se* at Jeanerette, Louisiana. Cartwright (83) observed a correlation of —.17 between rectal temperature in the heat chamber and summer gain of the same animals on pasture. While significant, this relationship is so low as to have very little predictive value. Both these studies lead to the conclusion that the best way to select for ability to perform satisfactorily under hot conditions is to maintain breeding animals under the conditions and select directly for performance rather than by selecting for a correlated character.

Qualitative Traits

The first research report on beef cattle breeding published in the United States (5) dealt with the inheritance of a qualitative character—horns. The comprehensive review of Shrode and Lush (45) on the Genetics of Cattle adequately covers the many subsequent papers which appeared during the next 40 years on the genetics of horns, color, and many abnormalities.

It had been tacitly assumed by many workers in the field that the inheritance of qualitative characters, while in many cases of economic importance, constituted problems separate and apart from productive characters such as growth rate, conformation, fertility, etc., which were generally considered to be strictly quantitative in nature. Then came the twin bombshells of the "Comprest" or "Compact" condition or conditions and dwarfism! Probably no hereditary characters—quantitative or qualitative—have ever caused so much concern and discussion, unfortunately at

times bordering on hysteria, and disruption of breeding plans in several major beef breeds as have these characters.

Lush (19) had reported a simple dominant gene which shortened the legs of Hereford cattle without visibly affecting other body proportions and termed it a "duck-legged" type. In the late 1930's and early and mid 1940's conditions differing from the "duck-legged" type and known as "Compacts" in Shorthorns and "Comprests" in Herefords appeared in these two breeds and for a time won extensively in the show ring, especially in steer classes (where there is still an occasional winner) but also in breeding classes where their popularity was short lived. These types were characterized by shortened legs, short, thick bodies, and the ability to fatten at small sizes. Although possibly due to different genes in the two breeds, each condition proved to be inherited as a simple one-factor dominant (39, 71, 72, 78). Each apparently represented the opportunity for a breeder to accomplish in a single generation what he'd often been struggling a lifetime to do through the application of conventional breeding systems in standard cattle types.

Research work with these cattle (discussed in the foregoing section) showed that they actually had few, if any, points of superiority over standard types of cattle in carcass quality and that they did have serious production shortcomings. The work also showed that the homozygous condition of the "Comprest" gene resulted in an extreme type of dwarfism characterized in many cases by bowed front legs. Few of these calves lived more than a few weeks. The gene must therefore be classed as lethal or semi-lethal. Although less extensively investigated, the "Compact" gene in the homozygous condition apparently produces a lethal of the "bulldog" type. Whether the two genes are different or are the same but with different modifiers in the two breeds is not known. Both are believed to be the same or similar to the "bulldog" lethal studied by Crew (12) in Dexter cattle and probably to the "guinea" gene (120) found in native cattle in the Southeastern United States.

Although they had undoubtedly occurred for many years (see Craft and Orr, 13, for a possible case) and had probably constituted a problem in certain herds earlier, the type of dwarfism reported by Johnson *et al.*, (51) in Herefords became widely recognized as a problem of major proportions in both the Angus and Hereford breeds in the late 1940's and early 1950's. Variously termed "shortheaded", "brachycephalic", or "snorter", these dwarfs are characterized by small size, short dished faces with protruding foreheads, undershot lower jaws, pot bellies, nervous incoordination, and breathing difficulties. Death rates are high among dwarfs but a few have lived long enough to reproduce.

As originally reported (51) and subsequently confirmed by a much larger body of data from breeders' herds (63) and by controlled breeding tests including both dwarfs and heterozygotes (93, 94), this type of dwarfism is apparently inherited as a one-factor recessive. Work involving

breed crosses (73, 102, 105, 120) demonstrated that the same gene is responsible for dwarfism in the Hereford and Angus breeds.

Comprehensive estimates of the frequency of dwarfism in the beef cattle industry, have not been obtained. One survey in western Nebraska (56) indicated a possible occurrence of 1 to 2% in beef cattle in that area. A survey by the American National Cattlemen's Association (85) indicated an overall frequency of approximately 0.2% in the major beef cattle producing States. There is reason to believe that this is an underestimate. Regardless of the overall frequency in the industry, it is known that frequency of dwarfism approached or exceeded 10% in some herds during the period when the problem was at its height. If this condition is inherited as a simple recessive, it would be expected that elimination of the dwarfs themselves would effect enough selection pressure against the gene to keep its frequency low enough that the occurrence of dwarfism would be rare. The reasons for its increase in frequency to the point where it constituted an economic problem for the cattle industry as a whole have not been completely determined. Two possibilities present themselves. First, it is possible that breeders could have selected for the dwarf gene accidentally if, purely as a matter of chance, the dwarf gene had occurred in a few particularly popular sires. The bulk of the evidence indicates that this probably did not account for the increase in dwarfism although the possibility cannot be entirely ruled out. The second possibility is that the gene is not completely recessive and that the heterozygous or carrier animals exhibit certain characteristics which cause breeders to favor them in selection, thus increasing the frequency of the dwarf gene. Several workers (51, 63, 71 and others) have suggested this possibility. Additional support for this hypothesis has come from recent studies (100, 106, 112) showing that carrier or probable carrier animals are *on the average* shorter in cannon bone length, shorter in body, and have shorter heads than those probably free from the dwarf gene. There is considerable overlap so that none of these characteristics constitute a diagnosis for the presence or the absence of the dwarf gene, but do indicate the possibility of breeders favoring carriers of this gene.

The most easily applied method for selecting against carriers of the dwarf gene is pedigree examination, excluding all animals known to have had carrier ancestry. During the past few years, breeders have been applying this technique, apparently very effectively. The price paid in terms of discarding otherwise desirable genotypes in the non-carrier segregates may be considerable. There is reason to believe that enough inaccuracies will occur in pedigree examination to make it unlikely that this will be a permanent solution to the problem, if a preference for carrier animals, in fact, exists and should continue to exist. A second method of eliminating carriers is through a progeny test program, in which prospective herd sires are bred to known carrier females. This is an effective method, particularly when the frequency of the dwarf gene is high, but is time consuming

and expensive and will become progressively less practical as the percentage of dwarf calves born decreases and the number of known carrier cows is reduced. Lush and Hazel (92) discussed the possibilities and limitations of these two methods in some detail.

The possibility of developing a method through which some physical or chemical test could be used to determine whether individual animals were carriers of this gene, has constituted an intriguing problem which has claimed much research effort during the past seven or eight years. Attempts at detecting carrier animals by tests of this type have included the profilometer (60, 68) which reveals differences in head shape; radiographs of lumbar vertebrae of young calves (104) which detect "compression effects" in the vertebrae; counts of certain blood cells following insulin shock by Lasley and coworkers at the Missouri Station; cerebrospinal fluid pressure (136) and perhaps others. At least some of these techniques reveal differences which are related to the dwarf gene but none are thought to be accurate enough to be relied on as the sole means of detecting carrier animals. Other techniques are under investigation. If the dwarf gene has an effect on the phenotype of animals in the heterozygous condition, it would seem probable that eventually some method or combination of methods will be found which can detect carrier animals with sufficient accuracy to be useful in breeding programs.

In connection with these studies and to provide leads for them, much work has also been done on the basic physiological causes of dwarfism. Neither endeavor has to date been entirely successful. Carroll *et al.* (53) reported that the snorter type dwarf was apparently due to a primary thyrotropic hormone deficiency and that they were cretins. Subsequent work (71, 118, 135) has not confirmed this hypothesis. Missouri and North Dakota work indicates strongly that the dwarf animals exhibit abnormalities in carbohydrate metabolism, which may be related to either pituitary or adrenal insufficiencies or both. Many workers suspect that some primary effect upon cartilage development may be the basic and underlying cause of the dwarf condition.

Trends in Efficiency of Producing Beef

In chronicling developments in beef cattle breeding during the past half century, little attempt has been made to indicate whether they represent progress or merely change. The writer believes that the present state of our knowledge makes it impossible to attempt more than a cursory and superficial evaluation of true progress. Some things would appear to be definitely of a progressive nature. In other cases, it is probable that developments have been detrimental to the overall efficiency of the beef cattle industry.

Estimates of overall efficiency in the industry in terms of feed units consumed per 100 lb. of gain (table 2) indicate an improvement of about

14% in efficiency when comparing the period 1910–15 with the period 1946–1955. However, figures were lower in the early 1930's than they have been since, thus making evidence for a consistent trend questionable. It is uncertain whether or to what extent the apparent improvement depends upon genetic improvement in cattle themselves and to what extent it depends upon developments in nutrition and particularly in management during the past half century. Cattle are thought to be marketed at younger average ages today than ever before and, this in itself may be enough to

TABLE 2. ESTIMATED FEED UNITS CONSUMED PER CWT. GAIN BY CATTLE AND CALVES (EXCLUDING MILK COWS) IN THE UNITED STATES [a, b]

Period	Av. feed units per cwt. gain	Period	Av. feed units per cwt. gain
1910–15	1076	1931–35	905
1916–20	1081	1936–40	949
1921–25	1088	1941–45	1012
1926–30	1010	1946–50	959
		1951–55	915

[a] A feed unit is the equivalent of one lb. of corn.
[b] Data courtesy of Farm Economics Research Division, Agricultural Research Service, United States Department of Agriculture.

explain the apparent improvement in efficiency. In an attempt to get some information which would have a bearing on the question of whether cattle have changed in average production efficiency, a number of trials in which beef calves or yearlings were fed on standard or "check" rations at experiment stations in the Central States, during the past 50 years, have been summarized. The validity of trends observed in these results rests on the assumption that the feeder animals used have, over the years, represented a reasonable cross section of the feeder animals available to the beef cattle industry, and that management has not appreciably influenced performance. Only lots of steers of British breeding full fed grain and legume or mixed hay were included. About half the lots received corn or sorghum silage and the only lots included not receiving protein supplements were those with all legume roughage. The data included are from readily available published sources and should be representative but are known not to be complete. The tabulation in table 3 is difficult or impossible to interpret due to differences in average length of feeding periods and in initial weights in different periods of years. There is, however, no positive evidence of improvement in either gaining ability or efficiency of gain since 1920 and apparent improvements as compared to the period prior to 1920 are of doubtful significance in view of the heavier initial weights and longer feeding periods in the earlier years. Thus, neither economic data or experiment station results provide clear cut evidences of improved efficiency of the industry as a whole.

The foregoing generalizations do not take into account quality of product produced. Definite objective information is lacking but those individuals who have had long contact with the beef industry almost unanimously indicate that beef cattle today have a greater ability to fatten at lighter weights and possibly at younger ages than those raised fifty years ago. Within limits this has undoubtedly been a desirable development although it is possible that this trend has at times gone further than is desirable and compatible with efficient production.

TABLE 3. AVERAGE PERFORMANCE OF STEERS FED STANDARD RATIONS IN FEEDING TRIALS[a]

	Years		
	1920 and earlier	1921–1940	1941–1957
I. Calves			
No.	159	636	258
Av. initial wt. (lb.)	469	383	447
Av. feeding period (days)	216	192	174
Av. daily gain (lb.)	2.00	2.20	2.16
Av. TDN per cwt. gain (lb.)	632	504	569
II. Yearlings			
No.	176	338	264
Av. initial wt. (lb.)	765	634	745
Av. feeding period (days)	166	192	151
Av. daily gain (lb.)	2.29	2.34	2.33
Av. TDN per cwt. gain (lb.)	773	644	707

[a] Data assembled from many sources.

Summary and Forecast

To summarize, the past half century has been an interesting one from the standpoint of beef cattle breeding. Progress has undoubtedly been made by the industry in developing types and kinds of cattle which meet market demands better than was the case many years ago. The evidence is less clear on whether the cattle available are, themselves, inherently more productive than those which were available for use by our grandfathers. Progress in beef cattle breeding research, during this half century and particularly during the past 20 years, has great promise of holding the key to the development of inherently more efficient cattle. It is hoped that definite progress in the industry as a whole can be reported long before this Society celebrates its one hundredth anniversary.

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FIFTY YEARS OF PROGRESS IN SHEEP BREEDING

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SHEEP breeders of the past 50 years have continued to improve on practices which began possibly 7000 to 8000 years ago (290). In fact the sheep was probably one of the first animals to be domesticated and man has long depended on sheep for clothing and food. Many of the methods of sheep improvement common during the past 50 years, such as selection for improvement of valuable traits and the formation of specialized breeds and types, must have been used before the time of recorded history. Our efforts in the last 50 years have been directed toward adapting these methods and the sheep with which we work to our changing needs. Furthermore, we have gathered and recorded many facts about sheep and animal breeding which have permitted the development of ways of applying these methods more precisely and effectively (278, 302, 313).

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Early History

Domesticated sheep were first introduced on the American Continent by the Spanish discoverers and conquerors (1). Columbus brought sheep to Hispaniola on his second voyage to the new world in 1493. Vessels that followed from Spain carried sheep in their cargoes to Hispaniola and Cuba. From these islands they were taken to the Isthmus of Panama probably early in the sixteenth century. English sheep were brought into the English Colonies almost as soon as they were settled (1). Sheep were brought to Jamestown, Virginia, in 1609 and were taken into Maryland at its first settlement. Sheep were brought to New York from Holland in 1625 while Swedish sheep were brought to New Jersey and Delaware. The first Spanish Merino flock of sheep was not established until 1801. Wentworth (171) has presented a detailed and very interesting history of the sheep industry in this country.

Conner (13) notes that the earliest known estimate of the total number of sheep in the United States was made in 1810 when there were about 7 million sheep with an average clip of 2 lb. of wool per head. By 1840 there

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were over 19 million sheep with nearly 60% in the New England and Middle Atlantic States. Following this period there was a decline in sheep numbers in the east accompanied by westward movements and increased numbers in the west. Numbers in the country as a whole increased to a peak of over 53 million head in 1844 (194). By 1908 there were about 48 million in the United States of which over half were in the Western States and Texas.

During the past 50 years sheep numbers at first declined for about 15 years and then quickly increased to over 50 million head by 1930 and remained high with a peak of over 56 million head, including those on feed in 1942 (194). Numbers then rapidly declined to a low of less than 30 million head in 1950 and since then have remained around the 31 million level (195, 301).

Increased Production per Ewe

Lamb and wool production have undoubtedly increased during this half century. Fleece weights averaged less than 7 lb. from 1908 to 1915 (194) while at present they average slightly over 8.5 lb. (301). This gain of about 2 lb. in 50 years may seem small in comparison with a gain of almost 5 lb. in the previous century but, of course, initial gains in production are usually made more quickly than those at higher levels. It seems probable that staple length and clean yield of wool for respective grades have both increased during the last 50 years but statistics are not readily available. Lamb production has also shown an upward trend from 85 to 89 lambs saved per 100 ewes, one year of age and older in the 1920's to 90 to 95 lambs saved per 100 ewes in the 1950's (318). Slaughter weights of lambs appear to have increased also (194, 301). These gains in lamb and wool production can be attributed to better feeding and management practices including better control of parasites as well as to gains from breeding although the latter has certainly been an important factor.

Some important shifts in the proportion of income from production of meat or wool by sheep have occurred in the past 50 years (194). In 1910 about 53% of the income from sheep was attributed to the sale of sheep, lambs, mutton and lamb and 47% to shorn wool. If the value of pulled wool was included with the shorn wool rather than with sheep, lambs, mutton and lamb, the proportions were 43 and 57%, respectively. There was considerable fluctuation from year to year with wool (shorn and pulled) producing 42% of the income in 1914, 65% in 1918, 44% in 1921, 57% in 1923, 37% in 1932, 63% in 1933, 46% in 1938, 57% in 1941, and 34% in 1948 which was the last year the statistics were given. The proportion of income attributed to shorn wool in 1948 was 25%. The proportion due to wool has probably increased recently because of the incentive payments on wool. It is obvious that it is difficult to be consistent in breeding for production of both lamb meat and wool with such tremendous changes in their relative values.

Purebred Trends

Purebred sheep probably have importance to production far greater than their numbers indicate because they serve as a source of sires for an important part of the sheep population. In 1920 there were almost 500,000 registered purebred sheep in the United States which represented slightly over 1% of the total sheep and lambs (27). The proportion would appear to be much the same today, although accurate and complete data are unavailable.

Many of the prominent breeds of today were well established in the United States 50 years ago. In 1920 the Shropshire, Rambouillet, Merino, and Hampshire comprised 86% of the registered purebred sheep (27). Other breeds represented were the Oxford, Lincoln, Southdown, Dorset, Cheviot, Leicester, Suffolk and Tunis. The Romney, Karakul and Corriedale had been first imported only recently. The proportion of purebred sheep of fine wool breeds was 42% as compared with 54% of the medium wool breeds and 4% of the long wool breeds. By 1930 the proportions were 41, 55 and 4%, respectively (61). The Rambouillet and Hampshire breeds increased in proportion of all purebreds from 1920 to 1930 while the Merinos and Shropshires declined, although they remained among the four breeds with largest numbers of registered animals. The long wool breeds also declined but the Southdown, Cheviot and Suffolk increased slightly.

In 1949 the Hampshire, Shropshire, Corriedale, Suffolk, Rambouillet, Southdown and Columbia breeds accounted for over 84% of the sheep registered (198). Since then the Shropshire breed has continued to decline in number of registrations while the Suffolk has increased markedly (332). The Merino, which appeared to be the leading breed in 1920, now makes up only about 2% of the regisrations. It seems apparent that breeds with more rapid growth rates and open faces are gaining in favor. However, the long-wool breeds have also declined in numbers since 1920 probably at least in part because of the popularity of the Columbia and similar breeds and their use in stabilizing western range crossbred sheep. The Suffolk, Corriedale, Hampshire, Dorset, Cheviot, Southdown, Montadale and Columbia breeds have shown increases in number of registrations from 1949 to 1957 (198, 332), while the Oxford and Romney have remained constant. The Rambouillet has declined in this period possibly due to the drouth in the Southwest and the Karakul has also shown a reduced number of registrations.

Experimental breed comparisons (67, 81, 92) have been uncommon with sheep. This may have retarded progress in not providing a more complete basis from which producers could discriminate among breeds.

New Breeds

One of the most striking aspects of sheep breeding in the last 50 years has been the development of new breeds. The Columbia, beginning with

crosses of the Lincoln rams on Rambouillet ewes in 1912 by the United States Department of Agriculture, is now found in nearly every State and nearly 8000 Columbia sheep were registered last year (103, 125, 184, 332). The Panama breed, started about the same time with Rambouillet rams on Lincoln ewes by Laidlaw and Brockie of Idaho, has also made an important contribution particularly in the West (216). The Romeldale, developed by A. T. Spencer of California, was based on crossing of Romney rams on Rambouillet ewes. The tailless or "No Tail" sheep has been bred by the South Dakota Agricultural Experiment Station using fat-rumped sheep as foundation animals (97, 227). This breed has not been released to private breeders. The Columbia, Panama and Romeldale breeds, made up of half long-wool and half fine-wool breeding are representative of large numbers of range and commercial sheep in the United States.

Another type which is very common on the Western ranges, often known as the "come-back" type, is composed essentially of one-quarter long-wool and three-quarters fine-wool breeding. A breed of this type is the Targhee, developed by the United States Department of Agriculture by crossing Rambouillet rams on Lincoln-Rambouillet, Corriedale-Lincoln-Rambouillet, Corriedale, and Columbia ewes (104, 125, 167, 232). Some other breeding was used but the breed is made up practically of three-quarters fine wool and one-quarter long wool breeding. The first crosses were made in 1926 and the breed is well established in several Western States. The Polwarth of Australia (73) is of similar origin resulting from crosses of Merinos on Lincoln-Merinos.

Other new breeds formed by crossing other breeds include the Debouillet from Delaine Merino-Rambouillet crosses (176, 205), the Montadale from Columbia-Cheviot crosses (143), and the Dormer breed of South Africa established by crossing the Dorset Horn and the German Merino (204). Crossing with a number of breeds has been used to improve the Navajo sheep of New Mexico (96, 181, 209, 210, 213, 221, 252) and the Columbia has been crossed with native Florida sheep (172). Rae (228) has reviewed work on breed formation and improvement through crossing. The development of new breeds and types through breed crossing has been an important factor in sheep improvement in the United States during the past 50 years.

Crossbreeding

Sheep breeders have long recognized that crossbreeding generally leads to increases in fertility and growth rate of the lambs (229). Increased milk production (89, 138, 139), body weights (258) and wool production (308) have also resulted from crossbreeding. In addition more valuable market lambs are produced by crossing mutton-breed sires on wool-type ewes, therefore, increasing the efficiency of production of both lambs and wool.

Many experiments have involved comparisons of various breeds of sires or dams for production of market lambs (52, 63, 71, 72, 89, 90, 114, 130,

145, 161, 214, 223, 244, 308, 309, 312, 316, 320, 321). The use of mutton-breed sires, such as the Hampshire or Suffolk on white-faced, wool-type ewes for market lamb production has been common during most of the last 50 years. Many of the resulting crossbred ewe lambs have been shipped to the Central, Eastern and Southeastern States along with many western ewes to be mated to mutton sires such as the Hampshire or Southdown for fat lamb production. This system of production has proven to be efficient and profitable.

Inbreeding

Sheep breeders have been concerned with the possibilities of inbreeding in an improvement program for many years. Studies on inbreeding occurring in pure breeds (57, 95) have been useful in showing the amount of inbreeding which has occurred in fairly large closed populations. In the 1930's a relatively large number of inbred lines of sheep were initiated by State and Federal agencies. Many of these were started at the United States Sheep Experiment Station, Dubois, Idaho. This action was stimulated by the success with hybrid corn. It also followed from the opinion that much of the possible gains from selection with sheep had already been made and that a new breeding system was needed.

Efforts to test the practicability of producing superior strains of sheep by developing and crossing inbred lines are still far from complete. There is general agreement that inbreeding results in loss of vigor as it is accompanied by some decrease in growth rate, body size, fertility and related traits (47, 151, 160, 163, 168, 179, 180, 259, 261). Crosses among inbred lines generally regain the lost vigor. It seems reasonable that crosses among the better crossing lines may possibly excell selected outbred groups. Many of the results regarding this opinion with sheep are found in data collected at the United States Sheep Experiment Station and Western Sheep Breeding Laboratory, Dubois, Idaho which are not yet published.

Inheritance of Traits

Information on the inheritance of various traits in sheep has been reviewed by Roberts and Crew (30), Miller (65) and Rae (302). Early attention was given to attempts at working out the mode of inheritance of many traits in a simple Mendelian manner. Breeds were crossed and the F_1, F_2, and sometimes later generations were studied (12, 15, 16, 23, 34, 35, 60). Particular interest has been shown in twinning or number of lambs born from single or twin mothers probably because of its economic importance (4, 7, 9, 10, 20, 21, 51, 62, 75, 83, 177, 244). The results of these and similar studies generally indicated that traits such as body weight or fertility were dependent on multiple genes. Gradually the efforts to explain the inheritance of all traits in a simple manner changed with

the realization that many traits were multifactorial in nature and that special statistical methods aided the study of these.

Considerable progress has been made through the last 50 years in determining the inheritance of traits, which at least in part, may be inherited in simple Mendelian fashion. These include color and pattern (2, 3, 5, 25, 26, 31, 33, 37, 41, 42, 43, 49, 75, 112, 116, 202, 323), horns (3, 5, 6, 46, 64, 88, 98, 100, 122, 137, 203, 211, 291), ear length (8, 18, 45, 122, 173), multinipples (24, 59, 147, 153), lethals or sub-lethals (32, 40, 109, 142, 144, 159, 197, 201, 270), other abnormalities (66), chalk face (36, 49), entropion (49), jaw defects (74, 78, 110, 149), birth coat and fleece structure (76, 99, 108, 134, 174, 175, 233, 246, 284, 285) and skin folds (200). However, evidence is accumulating that many of these may be inherited in a more complex manner than was earlier thought. In spite of this lack of complete knowledge much progress has been made in eliminating defects, in developing polled strains, in understanding the control of birth coat and fleece structure, and in using our knowledge of the inheritance of these many traits in breeding plans and studies.

In more recent years interest has been shown in increasing the number of simply inherited traits of which we have knowledge. Studies of inheritance of blood groups and traits (28, 29, 84, 85, 185, 196, 219, 272, 315, 329, 330) are laying the foundation for identification of parentage, for determining their relationship to merit, and for providing a check on changes in homozygosity with traits which are not evident to the practical breeder.

Of course, some attention has been given to the number of chromosomes in sheep (69, 86, 93, 106, 117) which seems established as 54 although there is disagreement as to the interpretation of the sex chromosomes (302).

Selection

In the late 1930's it became apparent that effective methods of selection had not been fully exploited by sheep breeders. Lush (79) and his students presented and developed statistical methods for understanding traits dependent on multiple genes. Following this many facts have been accumulated which facilitate selection such as estimates of heritability and repeatability, more accurate, objective and cheaper methods of measurement, information on adjustment for environmental effects, phenotypic and genetic correlations among traits, methods for constructing selection indexes, and effects of generation length on progress. Many of these aids to increasing progress from selection are not fully used by sheep breeders but their increasing use seems apparent.

Estimates of heritability, consisting of determination of the proportion of gain made in selection of parents which is passed on to the offspring, have been obtained to determine the relative emphasis to give various economic traits in selection. In sheep these have usually been obtained

from relationships among relatives. Estimates are available for a large number of sheep traits. One of the first reported was by Chapman and Lush (53) for birth weight. Many of these estimates are based on relatively small numbers under varying conditions and therefore considerable variability among estimates is expected. Nevertheless rough groupings of the various traits can be made regarding their relative heritability. Traits generally reported to have high heritability include face covering (131, 157, 162, 220, 238, 240, 253, 256, 279, 283, 286, 314), staple length (131, 152, 162, 170, 215, 220, 225, 238, 240, 253, 256, 273), skin folds (123, 131, 156, 157, 162, 215, 220, 235, 242, 273, 283), fiber diameter (253, 256, 283), and birth coat (260, 273, 282). Those appearing to be moderately heritable include body weight at birth, weaning or yearling ages (53, 121, 131, 152, 162, 182, 190, 215, 238, 240, 248, 250, 253, 273, 275, 276, 283, 292, 303, 325, 326), daily gain (256, 277), fleece weight, grease or clean (111, 129, 131, 170, 182, 215, 225, 226, 244, 251, 253, 256, 273, 276, 283, 292, 303, 322, 326), clean wool yield (215, 253, 256, 283), wool processing traits (283), index of overall merit (253, 283), fur characters (191, 248), color on legs (169), milk production (207, 263), date of lambing (255), resistance to parasites (183) and number of nipples (153). Traits with low heritability estimates include type of birth, twinning or multiple birth (119, 182, 218, 238, 257, 288, 293, 294, 324, 326), type or conformation (111, 129, 131, 154, 162, 170, 220, 225, 238, 256, 283) and condition or fatness (129, 154, 162, 220, 238, 283). Economic value is usually considered with heritability in determining relative emphasis in selection (247).

Progress in improving individual traits has been dependent on the development of accurate measures which could be made rapidly and cheaply. Measures have been developed for surface area (44), body form (48, 55, 70, 80, 127, 150, 254, 268), carcass traits (54, 87, 133, 140, 141, 178, 212, 222, 298, 306), semen production (82), wool production (68, 274, 300), fiber length (305), skin follicles and fiber number (128, 296, 299), fiber diameter or fineness (58, 146, 234), clean wool yield (22, 107, 135, 148, 165), and clean fleece weight (241, 295, 328, 335). Much remains to be done but developments such as Neale's device for estimating clean fleece weight (335) indicate that significant progress is being made.

Adjustment for environmental effects usually increases the accuracy of selection. Methods of achieving the same result by selecting within groups such as singles or twins can be used under practical conditions. Many studies are available showing the effect of factors such as age, type of birth, age of dam, sex, etc. (14, 77, 151, 155, 160, 163, 168, 189, 221, 239, 252, 267). Estimates of repeatability (19, 91, 111, 187, 206, 217, 243, 251, 253, 262, 263, 276, 297) have been helpful in combining various numbers of records for selection purposes. Other factors which speed progress from selection include reduction of generation length (136) and emphasis on selection of rams (208). Much greater selection differentials can be obtained for rams than for ewes because of the smaller proportion of rams needed to maintain flock size.

Studies of relationships among traits (39, 113, 199, 245, 249, 269) have aided in developing selection indexes. Selection for related traits often facilitate selection for traits which are difficult to measure such as staple length for clean fleece weight (120) body weight for lamb production (115), and face covering for lamb production (186).

Selection of sheep, where merit usually depends on a number of different traits, has been aided by the index method (126) for combining measures of several traits into one value. This provides a more efficient way of selecting for several traits at the same time than the use of independent culling levels or tandem selection for one trait at a time (116). Indexes have been used successfully with both farm (326) and range sheep (164) with evidence of increased selection pressure (164) and of probable progress with their use (208).

It has become evident in recent years that selection offers the most practical means for rapid improvement of sheep. Definite gains appear to have been made (208, 313) and much greater gains seem possible. Commercial producers of wool and lamb sometimes seem to be more aware of the need to apply selection pressure on production traits than are ram breeders and purebred breeders (310). Many selection and breeding plans have been proposed for sheep (11, 166, 224, 230, 266, 278, 310, 311, 313, 317, 334) which provide alternatives to fit a wide range of situations. Performance and progeny tests (50, 56, 94, 102, 158, 188, 193 231, 236, 327, 333, 336) are focusing attention on practical ways to apply effective selection methods to improvement of lamb meat and wool production. Competition among breeds and the tendency for commercial producers to breed their own rams when they become dissatisfied with the merit of the rams they buy are providing incentives for more rapid improvement of our pure breeds for economic traits.

The exhibition of sheep at fairs and shows has stimulated interest in sheep breeding over all of the past 50 years. These shows have served as a meeting ground for sheep breeders and breed ideals and standards have usually been consistent with show ring standards. The show ring has played an important part in determining the emphasis placed on various traits. In some cases this has led to emphasis on economically, unimportant traits such as head shape or absence of scurs or on traits with low heritability such as conformation or fatness. In fact selection for wool covering on the face was even encouraged by show ring and breed standards (38) although open face seemed advantageous (17). This trend seems to be reversed now following the demonstration that ewes with open faces produce more lambs (105, 132, 186, 265, 280, 287, 289, 297, 307, 314). Some criticisms of show ring and breed standards have been made (124, 237) although credit has also been given to the show ring for progress made (118). Progress from sheep breeding in the last 50 years would probably have been greater if emphasis in selection had been placed largely on production traits.

Breeding techniques for sheep, as in other farm animals are becoming

available which may lead to more rapid progress when used to accelerate present breeding or selection methods. Some examples include the use of hormones, light and temperature to breed sheep out of season, artificial insemination, and hormonal stimulation of ovulation rate. A fairly recent development involves embryo transplantation (264, 271, 281, 304, 319, 331) which may make new breeding procedures possible. Artificial variations in environmental conditions may be used to advantage in selecting for resistance to parasites (101, 192) or in selection for a trait of low heritability such as twinning.

The Next Fifty Years

Progress in sheep breeding in the past 50 years should provide some clues as to what to expect in the next 50 years. Increased emphasis on research, greatly increased knowledge and more rapid application of research results seem obvious. It seems likely that new techniques will be developed for measuring and evaluating traits, particularly for efficiency of feed utilization and meat quality. Also new techniques of breeding and selection seem probable. It is expected that more emphasis will be placed on production traits in selection and that continued progress will be made in increasing efficiency of production. Crossing of breeds and of inbred lines will probably became more common with increasing research information showing how most effective use can be made of such crosses. Continued development of new breeds and types to provide better adaptation to both environmental conditions and to our changing needs seems probable. In fact much of the above progress is essential if the increasing American population is to continue to enjoy the health and pleasure from eating lamb and the ideal comfort and protection from wool clothing and other wool products.

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FIFTY YEARS OF PROGRESS IN SWINE BREEDING

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SWINE breeding achievements up to 50 years ago were mainly the establishment and maintenance of the swine breeds up to that time. Methods employed in making and improving breeds were patterned after those practiced by breed founders and improvers in Europe, especially in Britain.

W. A. Craft

Three achievements, to which breeding has contributed, stand out in swine production during the last 50 years: 1) hogs reach market weight of 200 to 220 lb. about two months younger; 2) feed required per 100 lb. gain has decreased 80 to 100 lb.; 3) more pigs are saved per litter—since 1924 the increase is 1.6 pigs per litter. Progress is being made in a fourth achievement, namely swine carcasses. During the last 30 years definition has been developed as to what is desired in hog carcasses. In the early 1940's, the goal defined called for a yield of 50% of the live-weight in five primal cuts; ham, loin, picnic shoulder, shoulder butt, and belly, for hogs weighing 210 to 230 lb. Many hogs are now meeting the defined goal. Yield of primal cuts from hog carcasses of several breeds averaged 45.9% in 1946 in slaughter tests at the Ohio State University, similarly in 1955 the yield of primal cuts averaged 48.5%.[1] Cutting records by the Animal Husbandry Research Division, U. S. Department of Agriculture, Beltsville, Maryland, on carcasses from hogs of about 225 lb. live-weight show an increase in the yield of primal cuts from 44 to 50% of live-weight, during the last 30 years.[2]

Today emphasis is on lean cuts. Since about 1948 the definition includes a yield of at least 50% of the carcass weight in the four lean cuts—ham, loin, picnic shoulder, and shoulder butt. Yield of lean cuts appears to be increasing. Changes in trimming of the lean cuts and utilization of fatbacks during the last 10 to 15 years lend emphasis to the need for more lean, and less fat in hog carcasses. Breeding is proving to be an important factor in the improvement of hog carcasses.

[1] Information to the author from Prof. L. E. Kunkle, Ohio State University.
[2] Information to the author from Dr. R. L. Hiner, U. S. Department of Agriculture.

Breeding Practices and Experimental Breeding

Enthusiasm was kindled among animal breeders by the rediscovery of Mendel's principles. In 1903 the American Breeders Association was organized in St. Louis, Missouri. What they were thinking and hoping can be seen in the 8 volumes of Proceedings published. Although some were skeptical about general application of the principles, others were encouraged about possibilities of extending the breeder's art and skill.

Much of the experimental effort during the first 20 years of this half century was centered on learning about the inheritance of individual characters. Fertility, abnormalities in structure and function, color, and defects in conformation were studied. Trials pertaining to selection, inbreeding, crossing, and carcass traits also were reported. Smith *et al.* (1) of Scotland cite more than 600 reports from various countries of the world. Other reports have been added to the literature since then. Some of those who conducted early investigations or gave direction to the movement were: E. N. Wentworth, first at Iowa, later at Kansas State College, and with Armour and Company, Chicago, Illinois, Profs. Thomas Shaw and W. M. Hays of Minnesota, Dean Eugene Davenport of Illinois, Prof. F. B. Mumford of Missouri, Dean C. F. Curtiss of Iowa, Prof. W. E. Castle of Harvard, U. S. Secretary of Agriculture James Wilson, George M. Rommel and W. J. Spillman of the U. S. Department of Agriculture.

Comparison of Breeds, Grades and Types. Several investigators conducted trials comparing various breeds even before 1900. Curtiss and Craig (2), Mass. Agr. Exp. Sta. (3), Shaw (4) and Rommel (5) are examples. These comparisons did not supply an answer to the question being asked often. Which is the best breed? They indicated that breeds differed—no one breed was best in all performance traits.

Use of purebred boars was being urged. Between 1890 and 1930 pigs by purebred, grade, and Wild boars were compared as to conformation and growth rate. Examples are trials or demonstrations at the Alabama (6), Arkansas (7), Florida (8), and Iowa (9) Experiment Stations. A trial with the Wild boar and Landrace in Denmark was reported in 1953 (10). Three to five topcrosses usually produce stock that is closely similar to purebreds.

The most suitable type or size of hog has been a problem with swine breeders for many years. "Bacon" and "lard" types were the descriptive terms applied in the early years. Today "meat type" and "fat type" are terms used generally.

During the period 1900 to 1920 the type was changed from a small chubby type to a large rangy type. Three types—small, intermediate and large—were recognized from about 1912 to 1930. The differences between these were, perhaps, most extreme in the Poland China breed, but existed to a lesser degree in most others. By about 1940 an intermediate type prevailed, and extremely small type and large type animals were rare.

Earliest comparisons of types were between "bacon" and "lard" type breeds. Trials of particular interest were reported by the Minnesota (11), and North Dakota (12) Stations. Differences in performance between the two types and between the breeds usually were small. Experiment Stations began comparing the performance of small, intermediate and large type swine about 1917. Tests of special interest include those; at the Iowa (13), Illinois (14, 15, 16), and Indiana (17) Stations and at the U. S. Department of Agriculture Station, Beltsville, Maryland, (18, 19). Results differed in several respects but agreed generally on the important points. The inter-

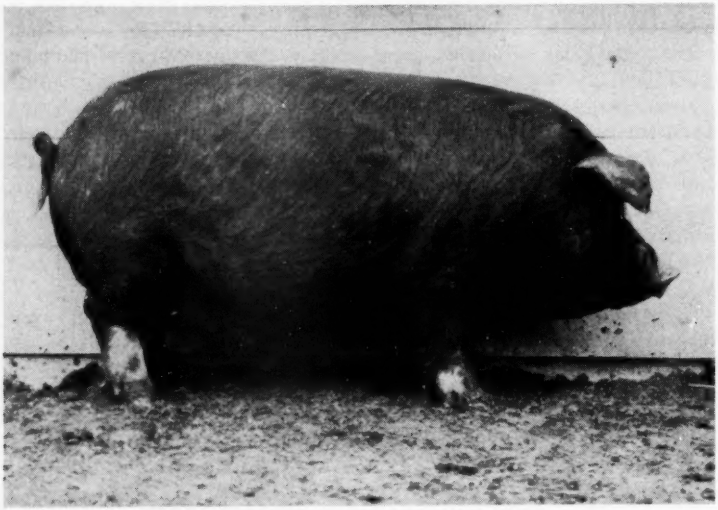

Figure 1. Small type of Poland China barrow. This type was common during the period of 1900 to 1910. (Courtesy Iowa State College.)

mediate type demonstrated the most favorable combination of litter size, rate of growth, economy of gain, and suitability of carcasses.

Swine Breed Associations have conducted annual Type Conferences, beginning in 1938, to focus attention of breeders and judges on the type that was currently considered most desirable. Since about 1946 all groups in the swine industry have stressed strongly the need for less fat and more red meat in hogs. Popular types of swine at various periods are illustrated in figures 1 to 4.

Interest in swine breeding methods has been focused largely on three courses of action; 1) mass selection on the basis of phenotype for conformation, soundness, balance, and breed characteristics; 2) inbreeding and crossing; and 3) progeny testing.

Selection. The idea of pure breeding which had crystalized by about 1900, excluded crossing and emphasized selection based on conformation, soundness, size for age, and symmetry, with some emphasis on pedigree. Showing was stressed, and the shows served to promote interest among breeders, to teach the currently favored type, and to advance improvement of the breeds. The various breeds have been used in purebreeding, grading-up toward a breed, and crossing to produce hogs for the market.

Hog producers have recognized, particularly in recent years, that the breeds differ in some important respects other than the "breed trademarks",

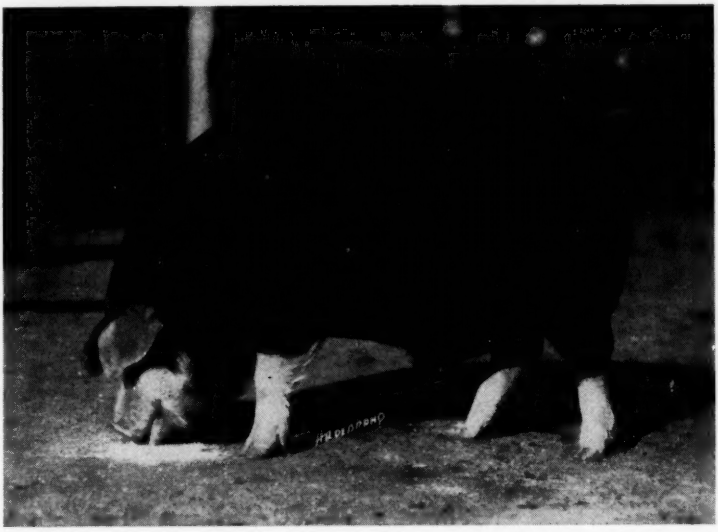

Figure 2. Reserve Grand Champion Poland China barrow International Livestock Show 1922. This type was in general favor during the period from about 1918 to the early 1930s. (Courtesy Iowa State College.)

else there would be little or no hybrid vigor or heterosis from crossbreeding. It has been recognized generally that some traits respond slowly, if at all, to selection as it is practiced. Need has been acknowledged for supplementary methods in selection, for improvements in such traits as litter size, growth rate, economy of gain and carcass desirability. In the late 1930's, Breed Associations began promoting Production Registry for litters that met a standard for numbers of pigs and weights of litters at eight weeks of age. Recently standards were added for age at market weight and leanness of carcasses. Litters, dams, and sires meeting the standards are certified. This practice aids in directing attention to litters, dams, and sires that meet the standards. During the last 20 years, barrow shows and

carcass demonstrations have been promoted as a means of improving hog carcasses.

As knowledge of genetics advanced, different methods of selection were investigated in the hope of learning how to improve selection practices. Correlations have been calculated between ratings of animals and their performance, between the rating of an animal and its progeny, between sibs and other relatives in respect to performance. Results usually show a positive but lower correlation between phenotypic appraisal of the ani-

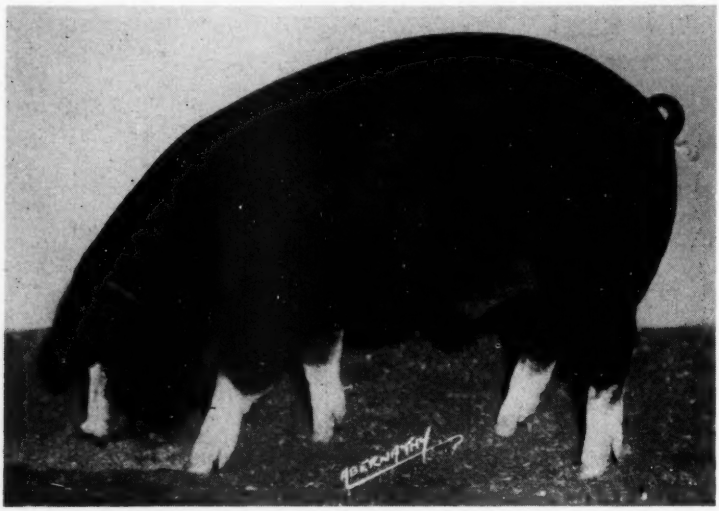

Figure 3. Champion Poland China barrow International Livestock Show 1941. This barrow represents the "Meat type" which has been stressed since about 1940. (Courtesy Iowa State College.)

mals and their performance, than is needed for it to be highly reliable in predicting performance (Lasley *et al.*, 20).

Performance of sows has been investigated in the United States and other countries with regard to repeatability of litter size and litter weight during their life time, as a means of evaluating the practice of culling or retaining gilts on the basis of their first litter. Details as to methods employed and interpretation of such studies were presented by Lush and Molln (21). Similar results have been reported by others in the United States and in Europe. A group of gilts selected because they averaged one pig more per litter than the average of the herd from which they are chosen, should average about 1/6 more pigs in future litters than if no attention were paid to size of their litters in choosing which to retain.

Four reports covering selection and the results obtained in experimental herds are of special interest. One of these is by Fine and Winters (22). The results were interpreted to be in accord with expectation, based on selection practiced, heritability of the traits, and inbreeding effects. Two points in a report by Dickerson *et al.* (23) are of special interest; 1) that selection practiced for litter size was largely automatic, because more pigs were available in the larger litters, 2) that response to selection was less than expected. Selecting solely for high and low rate of gain in separate lines at the Illinois Station (24, 25) under the same environment was effec-

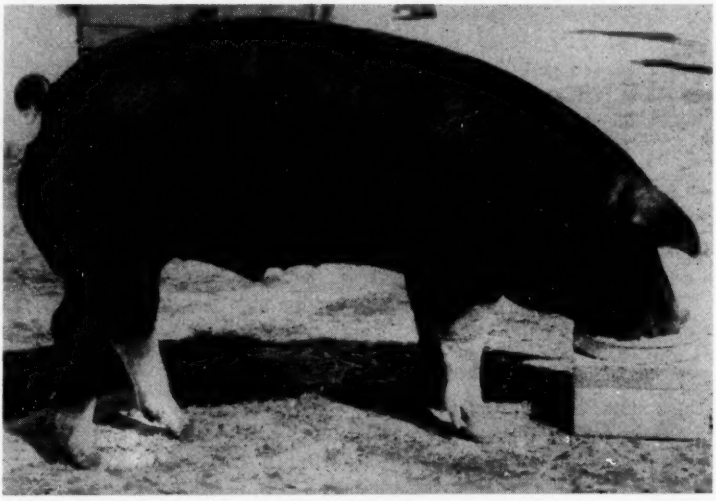

Figure 4. Poland China barrow—Grand Champion National Barrow Show 1957. The "Meat type" desired today is illustrated by this barrow. (Courtesy Poland China Record Association.)

tive but litter size declined in both lines. Likewise selection based only on economy of gain in opposite directions at the Alabama Station was effective in two lines (26).

Efficiency of three methods of selecting for several independent characteristics was investigated on theoretical grounds by Hazel and Lush (27); 1) selecting for one character at a time until it is improved, then selecting for another character; 2) selecting for a total score or index of net merit based on two or more characters; and 3) selecting for two or more characters at the same time, using independent culling levels for each. Calculations indicated that selection for one trait at a time would be least efficient, an index of net merit most efficient, and using independent culling levels for each character would be between the other two methods. Currently,

the method of independent culling levels seems to be the most widly used practice, generally. It has the practical advantage of permitting selection for each character when it is expressed without waiting until other characters are expressed before first cullings are made, and it does not require complicated calculations.

Advances in knowledge of genetics have thrown some light on the nature of selection problems. It is clear, that effects brought about through selection result from changing the frequency of the various genes with additive effects. The idea of purebreeding embraces the hope, that selection can steadily increase the frequency of such genes until animals homozygous for them will be produced. Such animals would have high transmitting ability.

If a desired gene is rare progress in selecting for it is slow, at first, because a rare gene causes little variation in the population. But as selection is continued, the frequency of the gene in question gradually increases and progress is accelerated until it reaches a maximum, then rate of progress declines. This is illustrated in genetic studies and recently published texts on animal breeding.

The swine breeder, at least in some respects, is selecting for a genetic intermediate. This does not mean that he is necessarily selecting for a heterozygote. In some combinations of genes in which two or more pairs of genes join to produce an effect both pairs may be homozygous—DDee for example, although one is dominant and the other recessive. Environmental effects may hide or even duplicate the effects of genes. Unlike genotypes may appear to be alike because of dominance or environmental effects. These situations confront the breeder continuously.

Genetic advances since about 1930 have focused attention on the genetic constitution of populations rather than that of single individuals. Publications of R. A. Fisher, Sewall Wright and J. B. S. Haldane, in the 1930's provide the basis of this development. The geneticist recognizes the swine breeders' problem as an effort to change the relative frequencies of the desired and the undesired genes in the whole population of a breed. Currently this is called population genetics. Many studies in applied population genetics are an attempt to estimate with reasonable accuracy the share of environmental and direct genetic effects including the usefulness of different breeding systems. The degree of heritability of the variations of a particular character and the intensity of selection pressure that can be applied, are factors with which the swine breeder must cope.

Methods of estimating the heritability of characters are based on correlations between relatives. These methods have been used, but sparingly for many years. Heritabilities are usually expressed as fractions of the total variation of a particular character—currently these are often used as percentages. A summary of heritability estimates for several characters of interest to swine breeders is presented in table 1.

TABLE 1. PARTIAL SUMMARY OF HERITABILITY ESTIMATES FOR SEVERAL CHARACTERS IN SWINE, BASED ON REPORTS OF INVESTIGATIONS LARGELY IN THE REGIONAL SWINE BREEDING LABORATORY, AND FROM SEVERAL FOREIGN COUNTRIES. (THE ESTIMATES ARE BASED ON PUBLISHED AND UNPUBLISHED DATA FROM MANY BREEDS.)

	Heritability %	
	Range	Approx. av.
Items of conformation:		
Length of body	40–81	59
Length of legs	51–75	65
Number of vertebrae	–	74
Scores of conformation	10–35	29
Type: (Based on small, intermediate and large type herds of Poland China)		
Within herds	–	38
Between herds	–	92
Performance characters:		
Number of pigs farrowed	0–24	15[a]
Number of pigs weaned	0–32	12[a]
Weight of litter at weaning	3–37	17[a]
Weight of pig at approx. 5–6 months	3–66	30
Growth rate (weaning to approx. 180–200 lb.)	14–58	29
Economy of gain	8–72	31
Items of carcasses:		
Length	40–81	59
Loin eye (area)	16–79	48
Thickness of backfat	12–80	49
Thickness of belly	39–72	52
Percent of ham (based on carcass wt.)	51–65	58
Percent of shoulder (based on carcass wt.)	38–56	47
Percent of fat cuts (based on carcass wt.)	52–69	63
Percent of lean cuts (based on carcass wt.)	14–76	31[b]
Carcass score	35–67	46

[a] Probably high.
[b] Probably low.

Inbreeding. During the last century pure breeding for the production of basic seed stock has become almost a world-wide practice. Pure breeding involves inbreeding, although the rate usually is low. Analysis of the amount and rate of inbreeding practiced in forming and maintaining several breeds of livestock was made from about 1920 to 1940, using methods developed by Wright and applied by Lush and others to several breeds. These studies reveal that the average decrease in heterozygosity per generation because of inbreeding, generally averaged about .5%.

Lush and Anderson (28) investigated the breeding practices used in forming and improving the Poland China breed. The rate of inbreeding from 1889 to 1929 was about .6% per generation—with a generation interval of approximately 2.5 years. Reduction in heterozygosis as a result

of inbreeding over that period was about 10%—this is less than results from one generation of half brother x half sister mating. There was only a slight tendency for distinct families to be formed and retained free from interbreeding with each other. Shifting from one famous animal to another not closely related to the one it replaced was evident. A somewhat similar investigation was made of the Danish Landrace by Rottensten in 1937, the results being similar to those for the Poland China.

Inbreeding played a part in the success of swine breeders who laid the foundations of the various breeds. To a large extent they fixed some desired characters by inbreeding using selected animals. Although inbreeding increased the ability of the animals to transmit their particular qualities to their offspring, it often lowered fertility, increased rate of mortality in the pigs, and reduced size. Therefore, inbreeding fell into disfavor and is avoided generally by most breeders.

Several experiments involving inbreeding pigs had been reported by 1930. The first of these in this country was started in 1908 at the Delaware Station, which continued for 10 years and was reported by Hays (29). Some other experiment stations which engaged in inbreeding pigs, were California, Iowa, Minnesota, Oklahoma, South Carolina and the U. S. Department of Agriculture. Trials of inbreeding are reported from other countries also.

All of the early trials were with small numbers, usually only a few litters. Mating plans were variable but generally mating of close relatives was practiced and in some cases the matings were not continued for more than two generations. Usually it is mentioned that selection was practiced. In general the results were not good. But some breeders have pointed with pride to their achievements in producing excellent inbred show animals (30). Clemson College, South Carolina, developed a successful show herd of inbred Berkshire from one boar and one sow. Only one line of pigs from the early trials is still in existence. It is a line of Poland China at Waseca, Minnesota started by Hodgson in 1924.

Mendel's discovery provided an explanation for the effects of inbreeding. It became clear at once that recessive genes, sheltered by their generally more favorable dominant alleles, are carried by many animals; that these are fixed and come into expression as readily under inbreeding as their dominant alleles. Dominant characters usually, are the progressive or desired expression, and recessives the retrogressive, often lacking in vigor.

Two views have developed largely from results obtained with inbreeding and crossing trials; 1) that it should be possible to establish, through inbreeding and selection, lines or breeds pure in all, or nearly all, genes favorable to vigor, so that the pure stock would be equal or superior to crosses; 2) that there is a favorable interplay between unlike genes which cause heterozygotes to show some degree of excellence beyond what can be achieved by pure types.

Analysis of the theoretical consequences to be expected from relatively mild inbreeding presented by Wright (31), suggested that selection could offset much of the detrimental effects of inbreeding. This thought provided encouragement for the idea that it should be possible, therefore, to produce inbred lines of high average merit by following mild inbreeding, even though that might not be so with the intense inbreeding which had been tried earlier. This idea tends to fit the concept of making the breeds increasingly pure or homozygous. Further, the idea of crossing selected inbred lines within a breed seemed to offer possibilities for advancing the genetic merit of breeds.

Crossbreeding. Crossing is an age-old practice in swine production. But after breeds were formed much emphasis was given by breeders and by writers on livestock production to purebreeding and grading as a breeding practice to replace crossing. In spite of this the tendency to crossbreed hogs was extensive and persistent.

Experiment Stations, from time to time, compared crosses with purebreds, beginning before 1900. A report by Shaw (11) is an example. Early trials were with small numbers of animals, and the design of trials was decidedly inadequate by current standards. Most of the records, however, indicate some advantage in favor of the litters arising from a cross, but the differences usually were small. It was not until after 1920 that such trials included numbers large enough to indicate clearly that crosses actually were superior in certain respects. Reports by Winters *et al.* (32), Lush *et al.* (33), Roberts and Carroll (34), Hutton and Russell (35), and Robison (36) establish a definite advantage in respect to increased survival and growth rate of crossbred pigs as compared to purebreds. Reports from trials in other countries present the same general picture as those conducted in the United States.

A point made for many years was that crossbreds should not be used for breeding purposes. The investigations by Winters *et al.* (32) made clear, however, that some advantages are to be obtained by using the crossbred sows. They presented data obtained on litters produced from crossbred sows back-crossed to one of the parent breeds. These show slightly less advantage over the purebreds than was obtained with a three-breed cross. But back-crossing by alternately using boars of two breeds was recommended because of simplicity. This scheme was called "criss-crossing".

When two breeds are alternated in crossing for a few generations without interruption, the pigs produced in any one generation get about 2/3 of their inheritance from the breed of their sire, and about 1/3 from the breed of the previous sire. In three-breed crossing, the pigs soon get about 4/7 of their inheritance from the breed of their sire, about 2/7 from the breed of the previous sire and the remainder, 1/7 from the breed of the sire used in the preceding generation.

Skeptical conclusions as to the advantages of cross breeding hogs were published by Carroll and Roberts (37). Their analyses, however, were biased systematically by the comparisons used; first, the decision was not made as to which of the two breeds to be compared with crossbreds was the "better" one until after the results were known, then the decision was made separately for each experiment from which records were compiled. That leads, of course, to the better breed being either X or Y, or a mixture of them in the averages, which are compared with the crossbreds. This biases the evidence against the crossbreds because there are two purebred groups to choose between in each comparison whereas there is only one crossbred group. Second, the characters were considered singly and separately. Usually one breed averages better in some characters and the other breed averages better in others. Heterosis effects are such as to make the net superiority of a crossbred as a whole animal somewhat higher than it is for each character separately.

Comparative results from purebreds and crosses as to number of pigs born and weaned per litter by sows in the Regional Swine Breeding Laboratory projects are shown in table 2. These results are in general agreement with reports from other sources.

During recent years, production and sale of "hybrid" boars has entered the field. Experimental evidence currently is inadequate to appraise this practice accurately. Trials with linecross boars (these might be called "hybrids" in the same sense as hybrid corn) produced by crossing two or more inbred lines of the same breed, have given good results generally in cases where their litters were compared with purebred boars without inbreeding in their background. A disadvantage of line-cross boars is the necessity of using two or more inbred lines to produce them.

Many studies have been made by geneticists, particularly during the last 30 years, seeking explanations for hybrid vigor arising from crosses. Attempts to explain hybrid vigor, and also the depressing effects of inbreeding, in Mendelian terms are based on two principal theories. The first is called the dominance theory. It is based on the observed association between recessiveness and detrimental effect, and assigns the increased vigor characteristic of crossbreds to complementary effects of favorable dominant genes brought into the cross from each parent. Inbreeding uncovers recessives and thereby results in deterioration, but crossing hides the effect of bad genes. Thus in the crossbred, some of the detrimental recessives coming from one parent are hidden by their dominant alleles coming from the other parent; an increase in vigor is the result. Since the number of genes for most of the important traits in swine is large, and linkage of desirable and less desirable genes is possible, the probability of a single breed, or an inbred line becoming homozygous for only the dominant or beneficial genes is remote. The second theory is that something about hybridity itself contributes to vigor. Thus in Mendelian terms, there would be loci at which the heterozygote is superior to either of the homo-

zygotes and the increased vigor is in proportion to the number of such loci. This idea is called over-dominance. In either case, vigor decreases with inbreeding and increases with crossing.

Development of Progeny Testing

A system of progeny testing swine was established in Denmark in 1907 for the purpose of increasing the market for Danish bacon in Britain. The plan was successful and the Danes soon gained an international reputation for their pig testing scheme. Details regarding the system and the results have been published notably by Lush (38) and in the regular annual reports (Clausen and Thomsen, 39).

Operation of the Danish system in addition to testing stations, includes state-recognized breeding herds called breeding centers which maintain required standards for carcasses, type, and health of the breeding stock. Denmark has had approximately 250 recognized breeding centers for many years. Essentially all of the boars used by Danish farmers have been produced in these breeding centers.

Changes in the Danish Landrace since 1926 in length of body, thickness of backfat and thickness of belly are shown in figure 5. Prior to 1926, only small changes occurred in these traits. But the age at which the pigs attained 90 kg. live-weight decreased from 198 to 182 days and feed units required per unit of gain decreased from 3.83 to 3.46. Feed units required per unit of gain had been reduced to 2.97 by 1957. Age at which 90 kg. live-weight was attained, changed only a little after 1926, but the pigs had become a little older when the starting weight 20 kg. was reached. Clausen (10), reported that from 1907 to 1953 pigs born per litter increased from 10.6 to 11.7, and pigs weaned per litter increased from 8.3 to 9.6 for the Landrace. Changes which occurred include improvements in management, feeding, disease control, and housing, as well as improvements in breeding.

Records obtained from individual feeding under the new plan of operations of the testing stations in Denmark inaugurated in 1951–1952 were reported by Fredeen and Jonsson (40). Results indicate that the method of individual feeding, as compared to group feeding of 4 pigs, reduced the variation in feed conversion, average daily gain, length of carcass and thickness of backfat. Under individual feeding, gilts were superior to barrows in both rate and economy of gain, which is in direct contrast with the results obtained under group feeding, and also with the results obtained in this country where barrows and gilts have been compared.

During the 1920's, progeny testing of pigs spread to other countries in Scandinavia, the continent of Europe, New Zealand, Australia and Canada, and more recently in Britain. The scheme was modified to meet the conditions in each country. Reports by Brekke (41), Hellberg (42), Johansson and Korkman (43), Osterhoff (44), National Bacon Hog Policy in

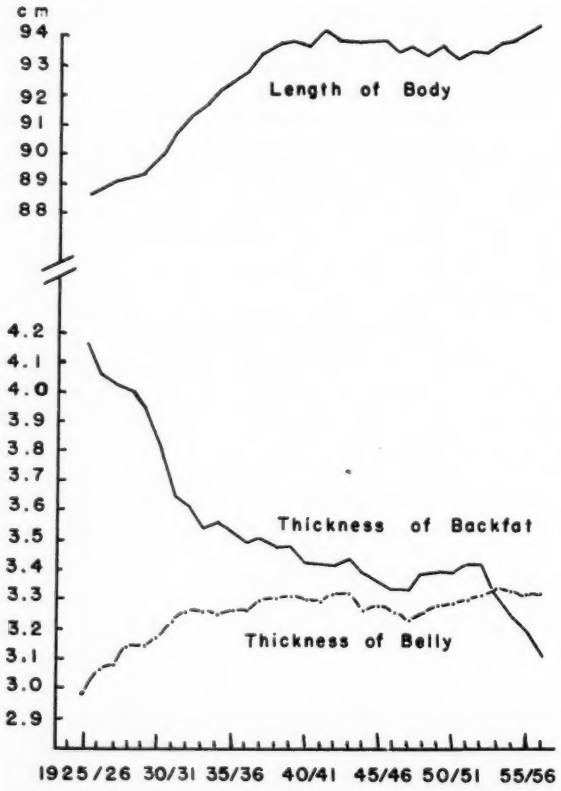

Figure 5. Length of body, thickness of backfat, and thickness of belly for Landrace carcasses at the Danish Testing Stations from 1926 to 1957. (From p. 27 Clausen and Thomsen, 39.) Results prior to 1926 were reviewed by Lush (38).

Canada (45), and Fredeen (46) reveal results achieved in several of the different countries. Fredeen did not find evidence indicating any change in the average of the traits from 1939 to 1950 for pigs in Canada. The degree of heritability indicated for the characters included in the Canadian program, should have produced improvement, if selections were based on the records obtained through the testing stations. It was assumed that Canadian breeders had not utilized the information obtained from the tests.

Record-of-performance testing was being discussed generally by leaders in swine production in the United States in the early 1920's. Need was recognized for developing more precise standards and methods for measur-

ing efficiency in pig production and carcass traits. A plan was developed for initiating a project with the cooperation of State Experiment Stations in Iowa, Minnesota, West Virginia and Wisconsin with litters submitted by hog breeders. Breeders discontinued submitting litters soon after 1930. The U. S. Department of Agriculture Station at Beltsville, Maryland, initiated litter testing in the experimental herd in 1926. Tests have been continued at the Iowa and Beltsville Sations with stock of experimental herds. A report by Culbertson *et al.* (47) relates some of the results. Interest in progeny testing pigs has increased again in recent years, as evidenced by the initiation of Production Recording of litters by the Swine Record Associations and the establishment of Swine Testing Stations in Ohio, Illinois, Indiana, Iowa, Minnesota, South Dakota and some other states.

Several studies have been made during the last 25 years of records from pig testing stations, to determine as accurately as possible what had been accomplished and to learn how to improve procedures to make testing most effective and less costly. These investigations draw attention to the genetic aspects of the hog breeders' problem with regard to performance traits, including carcasses. Also the number of litters by each boar that should be tested, and the numbers of pigs included from a litter were evaluated. Reports notably by Lush (38), Fredeen (46, 48), and King (49) are helpful in that regard. It is clear that records obtained from testing stations for pigs, may be useful to hog breeders in three respects:

1. As a measure of breeding value of the animals that produce the pigs tested. This is simply a progeny test for deciding whether to cull or to use parents of tested animals.

2. As a guide in selecting sibs or half sibs of pigs tested. The genetic value of this test is dependent on the genetic relationship of the animals tested to those remaining in the herd between which choices can be made.

3. As an indication of the tested pig's own merit, provided that the testing procedure does not require slaughter.

The basic reasons for progeny testing pigs currently seem to be for improving carcass traits, rate and economy of gain. In general, testing stations have not been utilized to measure animals which subsequently are to be used for breeding. Distinctive advantages are now being recognized for testing animals that are to be used themselves in the breeding herd. Testing of boars seems to be promising in that regard, particularly since practical schemes have been developed for measuring backfat in the live animals (Hazel and Kline, 50; Andrews and Whalley).[3]

Regional Swine Breeding Laboratory

Students of animal breeding were recognizing increasingly by about 1930 that it would be desirable to investigate more thoroughly the usefulness

[3] This method was developed at the Purdue Station and reported at the American Society of Animal Production meeting, 1954, but the report was not published. It involves the use of an instrument called a leanmeter.

of different breeding systems for improving performance characters in swine. A discussion of this was presented by McPhee and Hankins (51).

The idea of organizing and conducting swine breeding research on a regional basis through cooperation of experiment stations was advanced by Andrew Boss and W. C. Coffey of Minnesota, R. E. Buchanan and H. H. Kildee of Iowa, James T. Jardine, H. C. McPhee and Henry Wallace of the U. S. Department of Agriculture. After some exploratory effort in 1936, a group of State and Federal research men assembled to consider organizing and programming a Regional Project on Swine Breeding.

A plan was developed, approved by State Station Directors and the Secretary of Agriculture. Headquarters were established at Ames, Iowa in 1937, and projects were organized and started at once. The plan provided for organizing and conducting projects at State Experiment Stations with cooperation between the stations and the U. S. Department of Agriculture within the region of the North Central States. Oklahoma joined the group in that year. Ten state Stations and the U. S. Department of Agriculture are engaged in the trials.

Research undertaken concerns methods of selection, systems of breeding, inheritance of characters and physiology of reproduction. Projects that were in progress at the Iowa, Minnesota and Oklahoma Stations were revised and became a part of the regional effort. Initial breeding plans embraced the idea of forming inbred lines with selection based on Performance. It was believed, generally, that depressing effects of inbreeding commonly reported might largely be offset by selection, particularly in lines in which inbreeding increased slowly.

Plans outlined included also the forming of lines from crossbred foundations. This provision seemed desirable because of knowledge that; 1) such foundations offered opportunity for combining the best traits from two breeds; 2) opportunity for selection often is increased in early generations subsequent to crossing; 3) plant breeders had been successful in producing improved varieties from crosses.

Project Leaders have reported results with inbred lines and with crosses between them. A summary of results was published by the U. S. Department of Agriculture (52). These show that number of pigs born and raised, and growth rate tended to decline with inbreeding. Lines formed from breed crosses may have been less sensitive to the depressing effects of inbreeding than lines within the pure breeds. Results with these have been reported by Winters *et al.* (53, 54).

Farrowing and weaning results for litters produced in the various projects are presented in table 2. The litters are grouped according to the kind of breeding practiced. Inbreds of the various pure breeds are shown in column 1. Inbreeding averaged about 30%. Two types of linecrosses have been produced within the pure breeds, these are shown in columns 2 and 3. The topcrosses shown in column 5 were by inbred boars and out of outbred sows of the same breed as the boar. Litters shown in

TABLE 2. SUMMARY OF LITTERS PRODUCED IN THE REGIONAL SWINE BREEDING LABORATORY (1937–1956 INCLUSIVE) [a]

Items	Purebred breeding groups						Crossbred breeding groups				
	Inbred	2-Line crosses	3-Line crosses	Outbreds	Top crosses	Pure-breds excl. of inbreds	Sows inbred	Sows line-crosses or outbred	Sows cross-bred	Sires cross-bred	New breeds or lines from cross foundations
No. litters farrowed	9424	1572	1181	1564	118	4435	1323	1384	2190	117	3180
No. litters weaned	8664	1495	1134	1459	115	4203	1289	1358	2142	115	2985
No. pigs farrowed	75131	12229	9773	13910	1053	36965	10958	12095	20835	1114	28463
No. pigs weaned	46472	8716	7015	9441	761	25933	8180	9655	16084	883	20418
Percentage pigs weaned	61.9	71.3	71.8	67.9	72.3	70.2	74.6	79.8	77.2	79.3	71.7
Av. No. pigs farrowed per litter	7.97	7.78	8.3	8.89	8.92	8.33	8.28	8.74	9.51	9.52	8.95
Av. No. pigs weaned per litter/for all lits. fwd.	4.93	5.54	5.9	6.04	6.45	5.85	6.18	6.98	7.34	7.55	6.42
for only lits. wnd.	5.36	5.83	6.2	6.47	6.62	6.17	6.34	7.11	7.51	7.68	6.84
Percentage of litters wnd.	91.9	95.1	96.0	93.3	97.5	94.8	97.4	98.1	97.8	98.3	93.9

[a] Data included in this table were obtained through cooperation of the U.S.D.A. and the State Agricultural Experiment Stations of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Nebraska, Oklahoma, South Dakota, and Wisconsin. Grateful acknowledgment is made to the Stations for use of the records in this review, and to project leaders and their assistants who obtained the records.

column 7 were crossbreds out of inbred purebred sows. Crossbred litters shown in column 8 were largely out of linecross sows, but a few of these were out of outbred sows. Litters shown in column 9 were out of crossbred sows—these include the crosses produced through use of eight breeds, most of the sows were from two and three breed crosses.

A few crossbred sires resulting from crossing inbred lines of different breeds have been used. Litters by these and, also litters of lines from crossbred foundations are shown in table 2. The records on litters were not adjusted for age of sows, stations, seasons, years or other factors. Farrowings for each group were spread over more than three years, in most of them more than ten years. The proportions of sow and gilt litters are approximately the same in each group. A general comparison between groups seems valid.

It is clear that inbreeding has depressed survival of the pigs; that inbred sows do a better job with noninbred litters than they do with inbred litters.

The traits which have been most sensitive to inbreeding are number of pigs farrowed and weaned per litter, and growth rate, the latter is not included in the table. These same traits show most of the heterosis in crosses. The report of Chambers and Whatley (55) is an example for linecrosses. Results with lines inbred slowly indicate that swine breeders can maintain a line indefinitely as a closed herd, without serious loss in litter size and growth rate provided that inbreeding is kept at a low rate, not exceeding 3 to 5% per generation, and selection is applied continuously for performance traits. This would permit extensive exploitation of stock which rates high in carcass desirability and economy of gain. The latter two traits do not appear to be appreciably sensitive to inbreeding, nor do they seem to show much heterosis in crosses. Economy of gain is correlated to some extent with rate of gain, however. Thus it usually appears to be improved by crossing. Litters by inbred boars of some lines have excelled those by non-inbred boars on the same farm (Durham *et al.*, 56). Linecrossing and topcrossing trials are reported by Bradford *et al.* (57).

Currently there are three views as to the best method of forming lines; 1) that inbreeding should be at a low rate, using 15 or more sows and 4 or more boars per line of the same breed with selection against the undesirables uncovered by the inbreeding, 2) that inbreeding should be as rapid as possible using only 3 to 6 sows and 1 boar per line, or a single sow mated to her sire or a son, discarding the poorest lines after two or three generations of inbreeding, 3) that a cross of 2 or more breeds should be used as a base, inbreed slowly and select for the traits desired. These procedures are under investigation.

The development of lines from crossbred foundations as a way of combining the good traits of two different breeds was initiated by the U. S. Department of Agriculture in 1935 using Danish Landrace imported in 1934 and other breeds. Three of the lines formed from crossing the Landrace with other breeds have been recognized as new breeds. One of these

(Montana No. 1) was developed with the cooperation of the Montana Agricultural Experiment Station, another (Maryland No. 1) with cooperation of the Maryland Agricultural Experiment Station and a private breeder. The third (Beltsville No. 1) was developed at the Beltsville Station.

The Minnesota Station developed 2 lines (Minnesota No. 1 and Minnesota No. 2) from a crossbred foundation, and a third line (Minnesota No. 3) is in progress. Details relating to the development of the Minnesota lines have been reported by Winters *et al.* (54), Roubicek *et al.* (58) and Sumption *et al.* (59). A line (Palouse) has been developed from a cross by the Washington State Experiment Station (Ensminger *et al.*, 60). Each of the new lines mentioned has been accepted as a breed by the Inbred Livestock Registry Association.

These lines have shown a favorable combination of the traits of the breeds used in the foundation. Their performance has been good in most respects. Each has shown some merit in crossing to produce market hogs.

Inheritance of Characters. Many types of abnormalities have occurred in the pigs of the various populations in the cooperative projects. These have been scattered through the various herds but their occurrence has been too rare to permit appraisal of heritability except for two cases. One of these was a bleeding condition similar to hemophilia in man. It occurred in animals of a Poland China line in the Missouri project, and was reported as being caused by a recessive gene, not sex-linked as in man (Bogart and Muher, 61). Evidence was obtained that the condition occurs in other breeds also. The other abnormality is scrotal hernia for which Magee (62) reported 15% heritability. Also the data indicated a maternal effect of 15%. Heritability of several other traits is indicated in table 1.

Problems Which Seem to Warrant Emphasis

1. Genetic correlations between economically important characters. Evidence available suggests that negative correlations may exist between some of the traits for which improvement is sought. The extent that this is true needs to be determined. Some trials are in progress to supply additional information in that regard.

2. Development of practical selection indexes based on two or more traits. Since the swine breeder must use or reject an animal as a unit in selection, over-all appraisal of individuals is desired.

3. Additional trials at sampling breeds, combined with inbreeding to hold the good genes together. Testing stations seem to be a new source of sampling. Progeny testing at experiment stations is needed on both high and low rating animals from testing stations and from certified litters.

4. Making inbred lines with different rates of inbreeding, and comparing with-in-line selection with selection between lines. Trials in progress need to be amplified so that the merit of these procedures can be clarified.

5. Selection for crossing value. Trials of this sort are underway but larger numbers of animals are needed in this than are in use now to insure adequate evaluation of the effectiveness of such practice.

6. Physiology problems. Embryonic losses, factors that influence rate of ovulation, means of bringing a group of sows into heat at the same time, and artificial insemination in swine have not been investigated adequately.

7. Blood grouping. Cellular antigens in pigs should be identified, their genetic nature explored, and their association, if any, with the expression of economically important traits investigated.

Finally changes in size of farms and increasing application of technology in the whole field of agriculture are encouraging increased specialization both in production of swine seed stock and market hogs. Seed stock producers need to apply practices to improve precision in breeding, to increase the genetic merit of their boars so that the commercial hog producers can rely on their transmitting ability to a greater degree than now with respect to economically important traits. Production of seed stock is already becoming a more highly specialized business than formerly. Central Testing Stations, can aid in locating sources of stock superior in respect to economically important traits, and in making increasingly clear the differences between the breeds in that regard. Skillful utilization of superior stock in producing boars is indicated. Specialized commercial hog producers appear increasingly alert to information of the sort that can be obtained from on-farm-testing, and central testing stations. Likewise, further specialization in commercial hog production can be expected to utilize mating plans that produce as much heterosis as possible. Shifts in the numbers of some of the pure breeds during recent years are a reflection of the alertness of commercial hog producers to the strong and weak points of particular breeds, and the change as to what the market prefers.

Summary

Breeding practice and experimental trials with swine breeding during the last 50 years, are sketched briefly. Advances in genetics in respect to the topics included in the review are mentioned. Results show that; breed averages differ in important characters; emphasis on meat type hogs has increased; effort is being exerted to improve hogs in economically important traits through selection and breeding practice; variations in most of the important traits are sufficiently heritable to permit additional improvement; inbreeding tends to reduce litter size farrowed and weaned, and growth rate, but inbreeding can be used to hold together a stock containing unusually good genes so that extensive use can be made of such stock; characters affected adversely by inbreeding show heterosis in crosses.

Progeny testing of pigs in Denmark and Canada is reviewed. Results indicate that progeny testing can be effective in changing carcass traits,

economy of gain and growth rate of pigs. New developments in pig testing, and certifying litters appear to be constructive steps.

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FIFTY YEARS OF PROGRESS IN BEEF CATTLE NUTRITION

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ANYONE who has been actively engaged in cattle feeding since the turn of the century is likely to feel that great changes have taken place in the industry in the last 50 years and that these changes have been very rapid since World War II. It is true that significant changes have taken place, but these have come largely under the headings of practical utilization of feeds, management, facilities and transportation rather than in beef cattle nutrition. Anyone who analyzes critically the rations used is bound to be impressed that rations fed today do not differ greatly in content from those used 25 years ago.

J. K. Riggs

In the opinion of the writer the major contributions to the field of beef cattle nutrition in the last 50 years have been few. Space does not permit a complete review of the work done in all of these areas. Exhaustive compilations have been made in a number of areas and no attempt will be made to cover those areas in detail. Rather, the reader is referred to published works which already exist. In those areas where the information is scattered, an attempt is made here to summarize.

Beef cattle nutrition is part of the whole broad field of ruminant nutrition and can scarcely be separated distinctly from the nutrition of dairy cattle and sheep.

Energy and Protein Metabolism and Development of Feeding Standards

Determination of energy and protein requirements extends over a period of nearly 100 years but was actively carried forward into the 50 years now ending by Armsby who has exhaustively reviewed and summarized the earlier work in his books "The Nutrition of Farm Animals" (1) and "The Animal as a Convertor of Matter and Energy" (2). Major contributions in this field were made by Armsby and his group at Pennsylvania State College, particularly with regard to heat production in cattle, which led to development of the net-energy system of evaluating

feeds. He initiated cooperative investigations of the protein requirements for growth of cattle in 1917 under the National Research Council. His feeding standards based on digestible protein and net energy requirements are still well respected.

In later years, Brody and co-workers at the University of Missouri have carried the work forward and their findings are compiled in "Bioenergetics and Growth" which was published in 1945 (3).

Fraps (4) and Morrison (5), both beginning work about 1910, have contributed to the knowledge of energy and protein requirements in great measure. Fraps developed the "Productive Energy" method of evaluating feeds and published a useful feeding standard for beef cattle which was widely used in Texas for many years. In recent years, newer developments have lent some support to the "Productive Energy" scheme but Morrison's "Total Digestible Nutrient Values" and his feeding standards based thereon have had wide acceptance.

In 1945 the Committee on Animal Nutrition of the National Research Council, through its sub-committee on beef cattle, surveyed the available data and developed "Recommended Nutrient Allowances for Beef Cattle" (6), which states the quantative needs of beef cattle for all the recognized nutrients.

Chemical Composition and Digestibility of Feeds and Forages

One of the greatest factors contributing to successful beef production today is our knowledge of the chemical and digestible composition of feeds and forages and of the factors which influence those values. This great body of information developed by hundreds of workers in the animal, plant, and soil science fields and compiled by Fraps (4), Morrison (5), and Schneider (7) with the assistance of many others, forms the basis of our working knowledge of beef cattle feeding and nutrition. It continually expands (8) and has enabled us to increase our available feed supply by providing nutritive information on new crops as well as on by-products that were once wasted.

Utilization of New Crops, By-Products and Former Waste-Products

A number of feed crops have appeared and been accepted in the last 50 years. Chief among these is grain sorghum, which is becoming increasingly competitive with corn because of progress in breeding hybrid strains adapted to a wide variety of conditions, its adaptability to modern mechanization, and its established nutritive value. Forage sorghums are also gradually providing a greater portion of the roughage supply (9).

Sorghum grain has been found to be about equal to corn (90 to 95%) for fattening beef cattle (10, 11, 12). The grain varieties of sorghum can be used interchangeably with corn except for the low vitamin A value of the grain (13). The forages can also be substituted.

Recent work has shown that sorghum gluten feed (25% protein) can replace 50% of the grain and that sorghum gluten meal (51% protein) will substitute pound for pound for cottonseed meal in cattle fattening rations (14). This utilizes the major by-products of the newly developed grain sorghum processing for starch production. Many other examples could be given.

Utilization of waste products, which formerly posed serious problems of disposal, is illustrated by the development of dried citrus pulp and citrus molasses. Work at the California (15), Florida (16, 17), and Texas (18, 19) stations formed the basis for developing these new feedstuffs. The value of dehydrated sweet potatoes in times of surplus had been established in a similar manner (20, 21, 22, 23) as has the use of Irish potatoes (24, 25), sugar beet by-products (26, 27) and cotton gin trash (28, 29). Many more cases could be mentioned.

Utilization of Poor Quality Roughages

For many years much stress was laid upon the use of high quality roughages while lower quality roughages were ignored. The production of cottonseed by-products in the southern states made available large quantities of cottonseed hulls, which, because of their availability and ease of handling, were widely used in cattle feeding as early as 1883. By 1925 cattle feeders had worked out practical solutions to the problems of feeding them, but the main impetus to work on utilization of low quality roughages came as a result of the short supply of beef and high feed costs following World War II.

It has long been known (1) that low protein intake depresses digestibility of dry matter. This fact started a chain of investigations to determine the cause. Gallup and Briggs (30) found that the total digestible nutrients of prairie hay increased from 41 to 56% as the protein content of the hay increased. An increase in crude fiber digestibilty (56 to 69%) was also noted. Apparent digestibility of protein increased from negative values to 41%. Digestibility of dry matter in high protein hay was equal to that of low protein hay with 2 lb. of cottonseed meal added.

The group at Ohio, led by Gerlaugh, undertook an extensive series of investigations on the utilization of corn cobs. They found digestibility markedly influenced by protein level in the presence of starch but very little influenced in the absence of starch (31) and suggested (32) that starch was needed for growth of microorganisms in the alimentary tract. Gall then joined in the study (33) from the bacteriological standpoint and found nearly double the number of bacteria per gram of rumen contents from cattle on pasture as compared with the number in cattle on several winter rations. The organisms seemed to be generally the same morphologically, but there was a noticeable increase of fast-growing organisms correlated with an increase in amount of grain fed. Burroughs *et al.* (34)

then found that alfalfa hay, a water extract of dehydrated alfalfa meal, or the ash of alfalfa meal materially improved the digestion of corn cobs. They suggested the presence of inorganic nutrients in good alfalfa hay or meal which are essential to rumen microorganisms involved in roughage digestion. These workers further (35) concluded that nitrogen is essential as a nutrient for the growth of rumen microorganisms responsible for roughage digestion. Burroughs *et al.* (36), using the artificial rumen technique, found that cellulose in good quality roughages was digested efficiently without supplements of nitrogen, complex minerals or autoclaved extract of cow manure, but that these did improve cellulose digestion in poor quality roughages. Burroughs *et al.* (37) later found that molasses ash as well as phosphorus and iron were effective in stimulating urea utilization and cellulose digestion by rumen microorganisms *in vitro*. Evidence was presented that other elements besides iron and phosphorus are involved in rumen bacterial physiology in addition to sodium, potassium, calcium, magnesium, chlorine and sulphur routinely used in artificial saliva. Tillman *et al.* (38) indicated that iron and/or copper might be involved.

Beeson and Perry (39) set up experiments to test the effects of supplementing the nutritional deficiencies of roughages for beef steers. A supplement was formulated which supplied ample protein, calcium, phosphorus, cobalt and vitamins A and D. Fair results were obtained when this supplement was used with ground corn cobs as the roughage, but straws and cottonseed hulls gave disappointing results. When urea was used to replace from 1/3 to 2/3 of the protein equivalent supplied by soybean oil meal, there was no significant difference in growth rate of steers fed this supplement as compared to others fed soybean oil meal with corn cobs. Replacing 2 lb. of ground corn cobs with 2 lb. of alfalfa meal significantly increased growth. These workers later presented evidence suggesting the presence of unidentified factors in alfalfa meal which were responsible for the observed effect. Similar results were obtained by Gossett and Riggs (40) using poor quality hay for growing steer calves and it has long been known that even a small amount of alfalfa hay has great value (41).

The nutritive short comings of low quality roughages were established through experience, chemical analyses and digestion experiments. They are known to be high in fiber, low in nitrogen-free-extract and low in protein, calcium, phosphorus and carotene, and must be supplemented accordingly if they are to be utilized effectively.

Physical Form of Feeds

The development of fast, efficient equipment for grinding and mixing feeds has contributed much in the saving of waste and in changing methods of feeding cattle for market through the use of formulated rations.

Generally speaking, calves up to 6 or 8 months old chew corn, sorghum grains and oats so thoroughly that there is not much gained by grinding.

Smaller, harder seeded grains are generally slightly better when ground.

For fattening cattle over 8 months old, ground grains tend to increase gain and finish and decrease feed requirements per unit of gain (5, 42). Rolling or crushing has little or no advantage over grinding. Grinding or chopping good quality hays is not necessary, but may be economical in the case of fodders, stovers, or poorer hays because such feeds in ground form can be mixed with other ration ingredients to insure consumption without waste. Whey hay is fed in large amounts to fattening cattle, chopping may increase its value and the gain of the cattle slightly (5).

TABLE 1. COMPARISON OF FEEDING TIMOTHY-ALFALFA HAY IN BALED, CHOPPED OR PELLETED FORM TO STEER CALVES

Form in which hay was fed	Baled (long)	Chopped	Finely ground and pelleted
Number of steers per treatment	15	15	15
Av. initial weight, lb.	421	423	430
Av. daily gain (119 days) lb.	0.63	0.62	1.73
Av. daily feed intake, lb.	10.96	10.70	15.69
Gain per ton of feed, lb.	115.5	116.2	220.7

No method of feed preparation has attracted as much attention as cubing or pelleting has in recent years. Currently the high cost of fine grinding and pelleting appear to make the practice too expensive but the development of new processing methods could change this.

A dramatic improvement in gains of steer calves resulted from grinding and pelleting alfalfa-timothy hay as compared with feeding the same roughage chopped or long at the Illinois Station (43). Table 1 summarizes the results of the test.

It is apparent that the increased gain of these steer calves, nearly tripled by pelleting the roughage and was due to increased feed intake, but the added feed intake hardly seems adequate to account for the increase in gain. Similar observations were made at the California Station (44) with yearling Hereford steers fed alfalfa, but the increased gain appeared only on high roughage pellets, not on a pelleted complete ration running above 30% concentrates (45).

Pelleted feeds and rations clearly have a number of advantages in our present mechanized age if their use continues to show such favorable results, but the data with cattle are scant as yet, and recent work with sheep at the Texas Station (46) points up some possibly serious shortcomings of pelleted rations.

Fats in Beef Cattle Nutrition

Until recently very little attention has been devoted to the role played by fats in beef cattle nutrition but a considerable body of information has

now been developed. Early attempts to feed larger amounts of fat to cattle were disappointing when it was found that digestive disturbances resulted from levels of fat above 1 lb. per 1000 lb. body weight (5). High levels of fat in feeds such as rice bran have caused rancidity and affected keeping qualities and palatability.

A surplus of fats in the mid 1930's led to an investigation of the feeding value of crude cottonseed oil at the Texas Station. Quantities ranging from 0.1 to 1.0 lb. of the oil per head daily added to rations of silage and cottonseed meal for yearling steers resulted in increased gain and higher dressing percentage. High productive energy value of the oil was calculated (47).

World War II and its attendant need for fats brought about a change from hydraulic or expeller to solvent extraction of oil seed meals. This reduced the fat content of standard protein supplements from about 4.5 to 1% and caused some concern among cattle producers. Comparison of these meals for beef cattle showed no essential difference in their overall value, but Parham *et al.* (48) found a significantly higher level of blood fat in cows fed the hydraulic processed meal. No difference was observed in plasma vitamin A or carotene.

Raper (49), in work with beef calves, found when the fat (crude cottonseed oil) content of the ration was raised from 2 to 5.5%, the plasma carotene level rose significantly. Plasma vitamin A, and liver vitamin A and carotene were not affected. Palatability was a problem with mixtures above 5.5% fat.

By 1951 a surplus of both animal and vegetable fats had developed which resulted in work to determine possible utilization by beef cattle. Willey *et al.* (50) found that fattening steers fed rations containing 7.5% fat (cottonseed oil) required less feed per unit of gain than those fed only 2.9% fat. There was no improvement in rate of gain or carcass grade. As in previous trials, feeding a higher level of fat significantly improved absorption and utilization of dietary carotene and also brought about a very marked increase in level of blood fat. The high fat intake brought about a smaller deposition of fat in the 9–11 rib cut. Depot fat showed a lower iodine number and was therefore more saturated. Work reported by Reiser (51) indicated that the rumen flora will hydrogenate polyunsaturated fatty acids. Therefore, in light of the work by Willey *et al.* it may be that exogenous fat, which must pass through the rumen, is more completely saturated than endogenous fat.

Numerous studies have been conducted concerning the use of both edible and inedible animal fats. Matsushima *et al.* (52) found no difference between high grade edible and inedible unstabilized beef tallows as shown by weight gains. Increasing the tallow levels from 0.44 to 1.2 lb. per head daily tended to decrease the steer gains. No differences were evident in carcass quality, color nor hardness of carcass fat. The rations were palat-

able and no digestive disturbances occurred. Adding 5% of ground raw beef tallow to rations for fattening cattle at the Florida Station (53) increased both rate of gain and feed efficiency.

Adding unstabilized fats to feed mixtures may result in rancidity and some destruction of carotene or vitamin A. Fats stabilized with antioxidants prevent these occurrences (54).

Recent work has shown that young calves need 1 to 2% of fat in their diet (55).

New Zealand workers prevented bloat by spraying pastures with emulsified peanut oil and limiting grazing to the sprayed area (56, 57, 58, 59). Brown *et al.* (60) found a water-dispersible oil markedly reduced incidence and severity of bloat when fed at levels of 1 and 2% in the drinking water of steers grazing alfalfa pasture. This was less effective with feedlot bloat.

Branched and straight-chain fatty acids have been shown to be necessary for the rumen cellulose-digesting organism, *Bacteroides succinogenes* (61) and some of the fatty acids stimulate the *in vitro* fermentation by mixed suspensions of rumen bacteria (62). Phillipson (63) has reviewed the literature pertaining to recent developments in ruminant digestion including the volatile and short chain fatty acids.

It is becoming evident that fats play a much greater role in beef cattle nutrition than was once suspected.

Concentrate: Roughage Ratio for Fattening Cattle

The level of concentrate feeding for fattening cattle has been under study almost continuously during the entire 50-year period. Experiments at the Iowa Station (64) were concerned with light, medium and heavy grain feeding in 1904. Because of limited grain production in the Southwest the use of rations high in roughage was a necessity. Work done in Texas during the 1930's was therefore concerned with preparing cattle for market with high roughage rations and also the effect of limiting grain intake to 80% of full feed as compared with full feed.

Insofar as fattening is concerned, rations high in roughage do not permit high rate of gain or quick finish because the animals cannot consume enough feed to get the required energy, particularly if roughages of lower nutrient content are fed (47). This is in keeping with the recent findings regarding use of pelleted high roughage rations (43, 44, 45). It was possible, however, to produce desirable market finish on heavy yearling steers in approximately 200 days with rations containing only 25 to 30% of concentrate feeds including protein concentrate (65).

Full grain feeding produced slightly greater gain and higher finish than limited grain feeding as evidence by dressing percentage, carcass grade and the amount of separable fat in the carcass. Ether extract content of the lean was also higher. Limited feeding resulted in higher feed efficiency, however (66). These results have been borne out at other stations (67, 68).

Recent work with various concentrate: roughage ratios in complete mixed rations presents a somewhat confused picture (69, 70, 71, 72, 73). In Oklahoma tests, a decrease in feed intake as the concentrate content was increased from 35 to 80% tended to nullify the higher TDN content of the heavier rations and the cattle at all concentrate levels gained about the same (73). In the case of mixed rations, the animal cannot substitute concentrates for roughages as he can when unmixed rations are fed, and the energy content of the ration at higher concentrate levels may have a satiating effect. This may explain why gains and feed intake were increased when high roughage rations were pelleted but not when high concentrate rations were pelleted as shown at both Illinois (43, 74) and California (44, 45). If this is the case, substituting fat for grain or fat for roughage should bring about similar results in lowering total feed consumption, which was observed by Willey *et al.* (50).

Plane of Nutrition

The practice of purchasing stocker calves in the fall when numbers are plentiful and prices favorable has long raised question with regard to how they should be handled during late fall and winter months. It was established quite early in our 50-year period (75) that the better such calves are fed during this period, the less they tend to gain during the following spring and summer on pasture. The cattleman who wants to make maximum use of his pasture, therefore wants cattle which have been wintered in strong but thin condition. This means they have produced little weight increase for a period of several weeks or months. From the standpoint of producing the greatest quantity of edible beef the most economically, Guilbert *et al.* (76) have shown that cattle which make a continuous maximum gain to a given weight are more efficient converters of nutrients than are those fed at levels which do not permit such rapid development.

This principle of continuous growth raises a question with regard to the economy of striving for maximum weaning weights compatible with sustained production in brood cows. Weights of 100 lb. for each month of age at weaning are being achieved though not too commonly. This type of production probably represents the ultimate economy in converting low cost feeds to highly desirable human food.

The ability of young beef cattle to survive on restricted intakes of protein and energy and to recover from the effects when feed becomes abundant again is clearly shown by work recently reported and still in progress at Beltsville (77, 78, 79). Calves restricted to maintenance allowances of protein or energy for 6 months and then fed for rapid gain took more time to reach the same slaughter grade but required essentially the same amount of digestible nutrients per cwt. gain as their twins fed liberally for rapid growth.

The effect of restricted nutrient intake upon development and production of breeding cattle may be more important. Work at Cornell (80) with dairy cattle showed that raising heifers on 65% of Morrision's recommended TDN allowance and then feeding them liberally after first calving did not reduce mature size or milk production as compared with heifers raised at the recommended TDN level. Sexual maturity was delayed in the underfed heifers but after the first lactation, milk production was in their favor.

Similar results regarding weight and production of beef cows have been reported at Oklahoma (81) where groups of heifers were raised and then maintained for 10 years on bluestem pasture supplemented in the winters with 1 lb. or 2.5 lb. of cottonseed meal or 2.5 lb. of cottonseed meal plus 3 lb. of oats. At 5.5 years of age there was little difference in mature size although the young cows fed the low level of supplement took longer to reach this size because of heavier losses in weight during the winters early in the experiment. Weaning weights of the calves were not affected by level of supplement fed their dams but there was a distinct tendency toward reduced percentage calf crop and lower survival of cows as the level of supplement increased. In light of these findings it may be necessary to modify our present feeding standards to some extent.

The Use of Non-Protein Nitrogen Compounds

Cattle do not respond in performance to differences in protein quality as non-ruminant animals do (82, 83) because the protein of rumen microorganisms becomes available to the host animal lower in the digestive tract. It has been recognized since about 1890 that urea or other non-protein nitrogen compounds may replace a portion of the protein in rations for ruminants. Reid (84) has recently reviewed the voluminous works on the use of urea for cattle.

Experiments in which urea provided from 40 to 70% of the nitrogen for dairy calves four months of age or older showed that body weight was gained at a rate of 82 to 88% of that of calves fed rations supplemented with an equivalent amount of nitrogen from cottonseed meal, casein, peanut oil meal, soybean oil meal or tuna fish meal. Cereal grains or other high starch feeds composed one-third or more of the rations. Similar responses have been obtained with beef calves. In a few experiments growing cattle fed urea gained as well as others fed the common protein supplements, but from the great mass of data available, it must be concluded that urea is somewhat inferior to the conventional supplements for growth.

For fattening cattle, urea has a less definite value than for growth. It can be used quite satisfactorily to provide about 25% of the nitrogen in the total ration. At higher levels palatability may become a problem.

Possible toxicosis from the use of urea has been a deterrent to its general acceptance. Varying degrees of kidney congestion have been reported in

animals receiving rations with 1.4% of urea or more (85), but fattening steers have shown no kidney damage from rations containing 2.29%. Dinning *et al.* (86) produced ataxia in 20 minutes after drenching cattle with 116 gm. or more of urea. No difficulty was encountered from drenching with 57 gm., nor was any difficulty encountered in steers fed 200 gm. mixed in a ration. These workers concluded that urea mixed in a feed can be consumed in large quantities without ill effects, but the same or smaller quantities suddenly introduced into the rumen or esophagus can be fatal.

Recently, Berry *et al.* (87) reported very satisfactory results in self-feeding a urea-molasses mixture to beef cows. This liquid supplement was a mixture of blackstrap molasses, urea and phosphoric acid which was fortified with small amounts of vitamin A and trace minerals. It contained 30% crude protein equivalent and approximately 0.75% phosphorus. Twelve Brahman cows kept in drylot and self fed both the liquid supplement and either Johnson grass hay or cottonseed hulls for a period of 21 days, followed by a period of 7 days during which the supplement was self fed but the roughage was restricted. During the period of restricted roughage feeding, half of the cows consumed over 12 lb. per day of liquid supplement for a 7-day period, and one cow consumed the extremely high level of 14.8 lb. per day. This represents a daily intake of 1.5 lb. of feed grade urea without any ill effects, a level higher than has been reported in the literature. This same supplement has shown very favorable results under range conditions.

Minerals

Phosphorus. Perhaps one of the most dramatic and far reaching developments in beef cattle nutrition has been with regard to phosphorus.

For many years beef producers on the South African veld were confronted with low calf crops, poor growth and development of young cattle, and in many instances, with severe death losses among both growing and adult cattle. In fact, bone chewing, now accepted as the most common early symptom of phosphorus deficiency, was observed in interior Africa as early as 1780, but it remained for Theiler, Green and Du Toit (88) to conduct investigations and to finally establish the basis as aphosphorosis in 1924. Theiler in 1920, (89) announced the cause of "lamsiekte" as infection with *Clostridium botulinum* type D acquired by animals which chewed putrefied carcass debris. This permitted differentiation of this disease from "styfsiekte", "creeps", or "sweeny", and Theiler, Green and Du Toit definitely established phosphorus deficiency as the primary cause. These men produced the condition experimentally and found that feeding bone meal or dicalcium phosphate would prevent it. They recorded the phosphorus deficiency syndrome from slightly reduced productivity through osteophagia and seriously reduced productivity to osteoporosis, rickets, osteomalacia, cachexia, and death. They also produced evidence (90) that

the Ca:P ratio was of little significance in comparison with absolute deficiency of phosphorus. Theiler (91) observed pathologically that lesions of the bones of some of his heifers involved an excess of osteoid tissue the same as observed in rickets but he discounted vitamin D as a factor because solar radiation prevailed in his work.

Malan, Green and Du Toit (92) found that a drop in blood phosphorus precedes any outward clinical symptoms of deficiency and showed that inorganic blood phosphorus can serve for early diagnosis. The method of Malan and Van Der Lingen (93) for determining inorganic blood phosphorus has been adopted and used extensively in the United States and other countries for locating deficient soil areas and determining the extent of the deficiencies.

Work in America, Scotland and Australia was almost contemporary with that in South Africa. The work of Schmidt (94, 95) very clearly corroborates the results in South Africa on causes and prevention of "loin disease". Seddon (96) in Australia isolated the organism causing "bulbar paralysis" there.

These works led to an awareness and subsequent identification of phosphorus deficiency in soils and pastures, and of aphosphorosis of cattle from nearly all parts of the world—Scandanavia to Australia, and the Americas to India (97). Beeson (98) has reviewed the world literature on this general subject and prepared a map of the United States showing the distribution of mineral deficiencies.

The application of superphosphate to pastures in the Gulf Coast region of Texas greatly increased the yield and phosphorus content of the total pasture forage (99, 100). In general, application of superphosphate provided enough phosphorus in the forage for range cattle. Reynolds and Wyche (101) reported that fertilizer containing superphosphate more than doubled the yield of forage and increased its phosphoric acid content about 50% and its protein content about 20% on a heavy black clay soil. Fraps and Fudge (102) showed that many soils in Texas are low in phosphorus and that a high correlation exists between the phosphorus content of soils and the phosphorus content of the grasses grown on them (103).

It has been rather generally accepted that a phosphorus content of 0.11 to 0.13% and a calcium content of 0.23% are the minimum amounts of these elements in the dry matter of the vegetation required by range cattle. Many areas show much lower levels of forage phosphorus than this, particularly during drouth and winter periods, while calcium levels drop below 0.23% only occasionally.

South African workers (104) demonstrated a remarkable effect on the fertility of cows both as regards the percentage and regularity of calving under rather severely deficient conditions. Sterility resulting from deficiency was only temporary. Calves from phosphorus-supplemented cows attained sexual maturity earlier than those from deficient cows. No significant difference in birth weight of calves was observed, but at weaning the

difference was 16% and at 2.5 years 33%. Mortality rates were markedly lowered among the supplemented cattle.

Later work by Black *et al.* (100) showed a cumulative effect of phosphorus deficiency on reproduction and fully confirmed the results of the South African group in establishing the effectiveness of disodium phosphate through a controlled water supply. A significant point here is that the successful use of disodium phosphate tends to rule out any influence of calcium in the poor reproduction found in these two widely separated areas. It is probable that the cattle receiving disodium phosphate consumed more forage because of better appetite and hence had greater intakes of all nutrients from that source, but it hardly seems likely that this would contribute enough to change the picture greatly. Trace elements in addition to phosphorus had no effect.

Another salient point contributed by Black and co-workers was the effectiveness of phosphate fertilization of range land in South Texas (100, 105). Supplying phosphorus in the form of bone meal, disodium phosphate in the drinking water or by the use of triple superphosphate on the pasture all gave good results in normal seasons but the blood phosphorus of the group on fertilized pasture fell to a low level during a prolonged drouth. Phosphate fertilizers increased both the yield and phosphorus content of pasture forage. The yield was increased 33 to 84%, depending upon the rate of application. In general, phosphorus content of the forage increased as the rate of application increased, but protein content was not materially affected. The effectiveness of three methods of supplying supplemental phosphorus is shown in table 2.

Low phosphorus intake has been found to depress appetite, efficiency of feed utilization, and gain (97, 106, 107). Beeson *et al.* (106) found fattening Hereford steer calves to require 0.18% or more of phosphorus in their ration. Feeding experiments over a three year period showed that definite signs of phosphorus deficiency became apparent with rations containing from 0.11 to 0.15% phosphorus corresponding to a daily intake of 1.04 to 1.63 gm. phosphorus per 100 lb. liveweight. The steers on the low-phosphorus rations required about 30% more feed per lb. liveweight increase and their rate of gain was about 37% less than that of corresponding animals on a similar ration but with phosphorus content increased to 0.2% or more. Only after 8 weeks on the ration did animals show such signs of deficiency as low blood phosphorus levels, depraved appetite, and lowered food utilization. Supplementary phosphorus, whether supplied as bone meal or in cottonseed meal, was effective in preventing the deficiency.

Recently Burroughs *et al.* (108) have presented evidence that rumen bacteria may require a higher level of phosphorus than the host animal does to maintain health and inorganic blood phosphorus level and to promote bone development. On the other hand, Pope *et al.* (109) have shown no beneficial effect when phosphorus was added to the ration above 0.2%

TABLE 2. THE EFFECTS OF THREE METHODS OF SUPPLYING SUPPLEMENTAL PHOSPHORUS TO RANGE CATTLE IN SOUTH TEXAS

Item	Group 1 (no phosphorus supplement)		Group 2 (bone meal in self-feeders)		Group 3 (disodium phosphate in drinking water)		Group 4 (range fertilized with triple superphosphate)	
	Cows	Calves	Cows	Calves	Cows	Calves	Cows	Calves
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Average initial weight of cows	706		708		708		705	
Average weight of cows at end of								
First year	1,077		1,087		1,050		1,142	
Second year	916		1,029		1,051		1,106	
Third year	867		1,107		1,103		1,160	
Fourth year	882		1,140		1,155		1,107	
Fifth year	1,047		1,148		1,195		1,109	
Average weights of cows and calves at weaning time:								
First calf crop	774	500	939	524	956	529	993	544
Second calf crop	825	500	1,043	516	1,028	533	1,052	562
Third calf crop	789	460	1,015	545	1,039	519	1,007	557
Fourth calf crop	878	497	1,048	556	1,099	590	1,007	542
4-year average	802	489	1,011	535	1,029	542	1,015	551
Average number of days between calvings	459		365		367		364	
Average annual supplement or fertilizer per cow			56		73		376	
Average annual weaned calf weight per acre		21		31		33		47
Average calf crop weaned, %		64		88		92		96

of the dry matter. As shown by range trials (110), winter pasture forage may be critically low, but most fattening rations for cattle contain at least this much. Wise *et al.* (111) found the minimum phosphorus requirements for dairy calves to be approximately 0.22% of the air dry ration at ages of 12 to 18 weeks.

Calcium. While there is likely to be a shortage of phosphorus in range forages, particularly during dormant periods brought about by winter weather or drouth, calcium deficiency is comparatively rare (100, 112). A level as low as 0.23% calcium is not too frequently encountered and the use of bone meal or dicalcium phosphate, both good sources of calcium, did not result in improving growth of young stock or reproductive performance of mature cows as compared with the use of disodium phosphate under Texas conditions.

In contrast, however, when cattle are placed in drylot and fed heavily on concentrate feeds with only limited amounts of roughage the situation is reversed. Concentrates are generally good sources of phosphorus but poor sources of calcium. Under these circumstances, unless legume hay is fed

as the only roughage, added calcium may be needed since the non-legumes contain around 0.5% of calcium (cottonseed hulls, 0.13%) while the legumes generally contain more nearly 1.5%.

Extensive work by Weber *et al.* (113) at the Kansas Station has shown that fattening rations of grain, protein supplement and carbonaceous roughage produced substantially lower and more costly gains than the same ration with a limited amount of alfalfa hay added. Adding 0.1 lb. of ground limestone as a calcium supplement, however, permitted the cattle to gain almost as well as when alfalfa was included in the ration and bone strength was markedly increased. This has been confirmed at other stations and it is now recommended that fattening cattle receiving less than 2 lb. of good legume hay per head daily in a full-fed ration of grain, protein supplement and carbonaceous roughage should receive 0.1 lb. of a calcium supplement in addition. This can be mixed in the feed or supplied as a mineral supplement with salt.

Trace Elements. Relatively few trace element deficiencies are recorded for beef cattle. Marston (114) has reviewed the work on cobalt, copper and molybdenum and Underwood (115) has portrayed some trace element inter-relationships in animals.

Sjollema (116) discovered the cause of a wasting disease of cattle in northern Europe in 1933 and established its cause as copper deficiency. He found that cattle on pastures with 2 to 3 ppm of copper in the dry matter showed emaciation, anemia and loss of appetite and responded when copper was administered. Pastures showing 7.5 ppm in the forage he regarded as "healthy", and those with 20 to 30 ppm in the dry forage satisfactorily cured affected animals. An excess of molybdenum tends to interfere with copper metabolism and may increase the requirement as a result (117). Copper toxicity can occur at higher levels of intake over a period of time. Copper deficiency has been reported from Australia, Europe, New Zealand, South Africa, Scotland and various areas of the United States.

Cobalt deficiency has been identified in Australia, Canada and the United States. Animals become listless, lose appetite and weight, then become weak and finally die. On so-called "salt sick" soils of Florida large areas were at one time abandoned for cattle production because it was stated, "they just wont live on this land" (118). Extremely small amounts of cobalt are required for cattle. Pastures reported deficient contained only 0.01 to 0.07 ppm of cobalt, while those showing 0.07 to 0.30 ppm were found adequate (119). The requirement for cattle appears to be about 0.1 mg. daily per 100 lb. body weight. Cobalt applied in commercial fertilizers to deficient soils may increase the content of plants (120).

Iodine deficiency has been observed in beef cattle in the northern parts of the United States across what is known as the goiter belt (98). It has been depicted as producing dead or weak calves showing a marked goitrous

condition (121). Some calves not so seriously affected may survive and the enlargement of the thyroid gradually subsides. The requirement for iodine has not been definitely established but Greim *et al.* (122) have recommended the use of iodized salt with 0.01% potassium iodide stabilized to prevent loss of iodine. This is a widely used practice which is effective.

A very significant contribution to knowledge of beef cattle nutrition has been with regard to the influence of selenium in the northern great plains region, particularly South Dakota and Wyoming. Here plants of the genus Astragalus have the ability to absorb and accumulate as much as 2000 to 2500 ppm of selenium on a dry basis while other plant species growing with them show only 5 to 50 ppm. These plants are toxic to cattle grazing them but when the plants die and decay other plants can take up the selenium they have accumulated and also become toxic (123). Chronic toxicity is caused by rations containing as little as 8.5 ppm selenium. Growth is slowed in young animals before other symptoms develop, and the young are more susceptible than are older animals. This work has been reviewed by Moxon and Rhian (124) who later reported that salt containing 25 ppm of arsenic has given good protection from the disorder when supplied to cattle (125).

Vitamins

The remarkable symbiotic relationship with lower organisms in the rumen supplies cattle with the needed members of the vitamin B complex and vitamin K so that no dietary requirement is known at least for animals past the suckling stage (126). The discovery that cobalt is structurally a part of the vitamin B_{12} molecule has explained the need for cobalt to a great extent. Vitamin K is of consequence in cattle only in the case of hemorrhagic sweet clover disease. Spoiled sweet clover contains dicoumarol which decreases prothrombin in the blood and causes hemorrhages which may cause serious death losses (127).

Vitamin A. Disorders in fattening cattle now known to be caused by vitamin A deficiency, were described before that vitamin was discovered. Such disorders were associated with the use of rations in which protein supplements were fed without grain along with roughages of poor quality. Among early investigators to study this problem were Connell and Carson beginning in 1896 (128), Burns and Metcalfe (129) and Curtis (130). It was not until 1930 that Halverson and Sherwood (131), collaborators of Curtis in the work started at the North Carolina Station in 1908 (130), reported work showing that the major factor involved in injury to steers fed for long periods in dry lot on cottonseed meal and cottonseed hulls was a vitamin A deficiency. This was confirmed at the Texas Station in an experiment started in 1934 and first reported in 1935 (132, 133). Texas commercial cattle feeders, however, were using alfalfa hay as a supplement to rations of cottonseed meal and hulls as early as 1923, having observed

that the so-called "meal sickness" did not result when alfalfa was included in such rations.

This was about the period that Steenbock *et al.* (134, 135, 136, 137, 138, 139), Coward (140), Drummond (141), Euler *et al.* (142), Moore (143, 144), Karrer *et al.* (145, 146), and Kuhn *et al.* (147) were busily engaged in establishing the relationship between carotene, vitamin A and green color of plants.

Moore (143, 144) established that carotene is converted into vitamin A in the animal body and is stored in the liver. Guilbert and Hart (148) found that steers starting with good body stores of vitamin A showed a progressive loss of liver reserves when fed a deficient diet for varying periods of time. Hickman (149) suggested, and Frey and Jensen (150) confirmed, that the rate of expenditure of vitamin A from the livers of cattle is directly proportional to the magnitude of the reserves available. Riggs (151) established that the time required for depletion of body reserves of range-raised cattle was dependent upon the amount stored as influenced by age of animals. He indicated a relationship between rainfall, carotene content of range forage and body stores of carotene and vitamin A. Older animals grazing green forage for considerable periods tend to build up large stores. Newborn calves have little or no storage (152) depending upon the intake of the dam; however the diet of the cow during the latter part of pregnancy can influence the carotene and vitamin A reserves of the newborn calf (153, 154).

The relation of dietary intake of carotene and vitamin A to the levels in the blood have been studied extensively. It has been shown that carotene intake and plasma carotene vary quite directly while plasma vitamin A tends to reach a maximum at which it levels off (13, 155, 156, 157, 158, 159, 160, 161, 162). It has also been shown in dairy cows that the level of carotene and vitamin A in the maternal plasma drops at the end of gestation and that the colostrum contains a much higher level than normal milk (159, 160). This may not be so distinctly true with beef cows (162). During the month following parturition the maternal plasma values rise. Plasma carotene and vitamin A of the calves increases rapidly during the first few days of life and then tends to decline to a normal level with the change from colostrum to normal milk (162) in keeping with the dietary intake of the dam. Hence, calves nursing cows on dry pastures and grazing dry grass themselves may have small body reserves at weaning time, and, if placed on feed on low carotene rations at that time, may develop clinical symptoms in a very short time (151).

Smith and Wang (163), in studying the carotene content of grassland herbage, found in all cases the carotene content was greatest when the plants were young. The predominant factor influencing carotene content was stage of growth. Hart *et al.* (164) demonstrated that range forage in California becomes deficient in phosphorus, protein and vitamin A. Watkins

(165) showed that mesa dropseed grass in southern New Mexico looses its carotene content when it dies after frost while black grama holds its carotene well into the winter. Watkins *et al.* (166) also found that the blood plasma carotene of Hereford range breeding cows was rather high during a 5-year study except for two years during the winter and spring months. In later work, Watkins and Knox (167), working with Hereford cows grazed on dormant range, found the blood carotene of the cows well above the requirements shown by various workers, indicating no serious deficiency over an 8-year period even in the most critical season. This suggested, Ross *et al.* (162) confirmed, that the seasonally low intake and attendant low plasma carotene and vitamin A may not be as critical as indicated by the California group (152). On the other hand, it may lend support to further investigation of interrelationships of energy, phosphorus, protein and vitamin A.

Hart *et al.* (152, 164) studied a severe outbreak of vitamin A deficiency under natural conditions in a herd of 250 head of which 100 died. Reproductive failure was complete in 25 to 30 cows calving at the height of the deficiency. All the calves were born weak, had severe diarrhea and died in 1 to 5 days. These workers recorded the symptoms as 1) birth of dead or weak calves with or without eye lesions, associated with retention of the placenta, and simulating infectious abortion; 2) severe diarrhea in weak, newborn calves, simulating white scours and 3) eye lesions, particularly in immature animals, simulating infectious keratitis. They also observed night blindness and ulcerated corneas, and found green feeds to be effective in alleviating the condition.

Bulls and cows do not necessarily lose their ability to breed even when they become night blind and have muscular incoordination. Degenerative changes of the germinal epethelium in the testes have often been demonstrated (168, 169). Vitamin A deficiency in bulls of breeding age causes a decline in sexual activity. Spermatozoa decrease in number and motility and show a marked increase in abnormal forms. Feeding carotene to deficient bulls again stimulates normal sperm production and sexual activity although complete recovery from testicular injury requires some time after the dietary deficiency has been corrected (169). Estrus may continue to occur when cows are deficient enough to have convulsions and muscular incoordination. Conception is often impaired at this stage. In pregnant cows deficiency results in abortion or birth of dead, or weak calves which soon die unless supplied a source of vitamin A (168). Calves blind at birth have been observed (13).

Davis and Madsen (158) reported that Shorthorn heifers restricted to 60 mcg. of carotene per kg. body weight daily before and during gestation gave birth to apparently normal calves, one of which suffered convulsions at one month of age and died two months later. Heifers which received 30 to 45 mcg. per kg. body weight gave birth to stillborn, blind or weak calves.

Hereford and Shorthorn cows showing 78 to 96 mcg. of carotene per 100 ml. of plasma produced normal calves, but a higher level was necessary for first-calving heifers. Payne and Kingman (170) reported that aged Hereford cows may maintain normal health and reproduction at 83 mcg. of plasma carotene but heifers should have at least 118 mcg. of carotene per 100 ml. of blood plasma. Heifers with a level of 97 mcg. showed clinical symptoms of carotene deficiency, so-called nutritional abortions and cases of retained placentas.

Cows on a low plane of carotene intake are unable to mobilize enough carotene and vitamin A in the milk to protect their calves from deficiency (171). Vitamin A content of milk, and to a lesser degree carotene, seem much more closely related to dietary carotene intake during lactation than to differential liver stores resulting from various levels of carotene intake prepartum. Supplementation of low carotene rations with 300 mg. of carotene per cow daily during lactation resulted in normal carotene and vitamin A levels in the plasma and livers of suckling calves. The rate of depletion of the liver stores of the cow during five months prepartum was also decreased.

Pregnant beef cows accumulate large stores of vitamin A when grazing spring and summer range. This will supply their needs during winter or short drouth periods even when carotene intake is very low. Young calves, however, may be expected to show symptoms of deficiency when nursing cows that are not permitted to consume at least small quantities of hay or other carotene-containing feeds (162, 172, 173, 174). Wheeler *et al.* (173) found that cows showed vitamin A deficiency symptoms only after 350 days on a ration of bleached hay and straw. These findings are in keeping with observations of cows and calves in cottonseed meal and hull feedlots in the southwest (175) and with findings on length of time required for depletion (151). Similar observations have been made by Colby *et al.* (176) with ewes.

Guilbert and Hart (168) showed that the carotene requirement is proportional to body weight. From feeding tests they estimated the daily requirement at 1128 to 1500 mcg. per 100 lb. live weight, based largely upon observations of night blindness in the animals being tested.

In Texas, Jones *et al.* (13) conducted exhaustive studies on the carotene requirement for fattening steers through feeding tests. They found the deficiency characterized by night blindness in the early stages. In later stages the cattle become less alert, may water at the eyes, show nasal discharge, suffer from solar heat, show leg and body swellings, become completely and permanently blind, lose appetite and weight, develop rough, dry hair, and die unless the condition is relieved. Green grasses and legumes, leafy green new crop legume hays, cod liver oil or other vitamin A concentrates were all effective in preventing or correcting the condition.

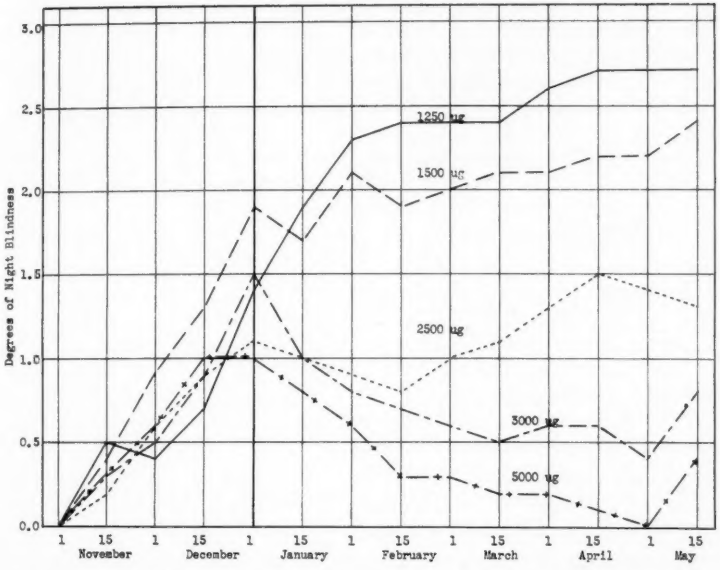

Figure 1. The influence of level of carotene intake upon night blindness. 0 represents normal night vision; 3 degrees represents complete night blindness.

Carotene in the ration was found to have no effect on gain or fattening as long as there are body reserves of carotene and vitamin A, nor does an abundance of carotene increase gain after the minimum amount required to maintain health is fed. The minimum of carotene for maintaining health was approximately 2000 to 2500 mcg. per 100 lb. live weight daily although 1500 mcg. allowed satisfactory fattening of steers in spite of minor symptoms of vitamin A deficiency.

Night blindness generally occurs far enough in advance of more serious symptoms of deficiency that it can be used for a guide as to when carotene or vitamin A must be incorporated in the ration to prevent serious trouble. Close observation is necessary, however.

The influence of level of carotene intake upon night blindness is shown in figure 1. Table 3 shows the relationship between level of carotene intake, rate of gain, plasma and liver carotene and vitamin A and night blindness.

Hormones and Feed Additives

Feed additives and hormone-like drugs have reecived more attention than any other field of applied beef cattle research in recent years.

A number of research papers have reported a growth stimulating effect of subcutaneous implants of diethylstilbestrol in fattening cattle. Unfortunately, some of the early experiments employed much too high levels and side effects which were undesirable from a marketing standpoint were observed even though the treatments did result in substantial increases in

TABLE 3. THE INFLUENCE OF CAROTENE INTAKE UPON GAIN, CAROTENE AND VITAMIN A IN BLOOD PLASMA AND LIVER, AND NIGHT BLINDNESS OF FATTENING STEERS

Carotene intake, mcg./cwt. daily	Daily gain, lb.	Carotene, ppm in		Vit. A, ppm in		Night blindness
		Plasma	Liver	Plasma	Liver	
836	1.44	0.2	—	0.2	—	Complete night blindness prevailed
1286	1.77	0.5	—	0.2	—	
1837	1.92	0.5	0.6	0.4	1.8	
2485	1.79	0.7	—	0.2	—	Some degree of night vision
2830	1.93	0.6	0.9	0.3	2.4	
3350	2.01	0.8	1.2	0.3	2.7	
5328	1.96	1.5	1.4	0.4	4.7	About normal

gain and feed conversion. Among the undesirable side effects were elevation of the tail head, low loin and stimulation of mammary development even in steers (177). These undesirable characteristics tended to discourage further work for a time until Burroughs (178) reported growth stimulation from feeding trace amounts of diethylstilbestrol to cattle without evidence of the undesirable side effects. Within a year large numbers of cattle feeders adopted the use of this material for steers so that it soon became more or less routine practice.

Dozens of feeding trials have been conducted experimentally to test levels of intake and to evaluate the effects in different feed combinations. As an average of 21 such trials using 10 mg. per head per day as the level of intake, for steers weighing 600 lb. or over, the drug has resulted in increasing feedlot gain 17% with a range of 4 to 37%. Feed saving has averaged 12%, ranging from 4 to 24%. Carcass grade and dressing percent show no significant change.

Following the highly successful use of the oral intake method, the use of implants has been reappraised. With the dosages lowered considerably so that side effects are not so pronounced, the implant method has also become widely used.

Methods of using stilbestrol in practical management including suckling calves, growing young cattle on pasture, and its effects on reproductive development and activity are being widely investigated. No compound has ever had as much impact on the beef cattle industry with as little information concerning its mode of action and effects in the animal body.

Recently, increased gain and feed efficiency in fattening steers have been reported from the use of the tranquilizing materials hydroxyzine and reserpine at levels of 2.5 mg. per head daily which is far below the level required for sedation (179). Much work is in progress in this area.

Thyroid inhibition of beef cattle by the use of 1-methyl, 2-mercapto-imidazole has been tried very recently with variable results (180, 181).

Work at Purdue University in 1953 (182) showed that chlortetracycline at a level of 24 mg. per cwt. liveweight administered orally by capsule daily to suckling beef calves decreased scouring and gave an apparent growth stimulation. Calves and yearlings fed 75 mg. per head daily in high roughage rations showed significant improvement in gain and feed conversion. Since that time many feeding experiments have been conducted to evaluate the practice. A summary of 32 experiments shows that feeding antibiotics at about the 75 mg. level has increased gain 6% at a saving in feed of 4% on the average. In 10 of the 32 trials there was either no improvement or a decrease in gain. Gains over all experiments ranged from a decrease of 8% to an increase of 21%.

The antibiotics have been quite generally accepted in large commercial feedlots where they may tend to reduce sickness and death losses, particularly if fed at higher levels at the beginning of the feeding period (183). The degree of response to the inclusion of antibiotics may be presumed to vary with feedlot conditions and disease levels.

Tests with a new "chemobiotic" have given a variable response.

Needs of the Future

The principal need for future progress in beef cattle nutrition is for basic research into the physiology of digestion and nutrient utilization as related to the fundamentals of performance as meat animals. Better understanding of rumen functions will be helpful. There is great need and opportunity for investigations of the inter-relationships of nutrition and genetics. Gaining ability or growth rate, has been found to be quite heritable, but we must admit that measurements of gain or growth rate are only a very gross method of measuring the net effect of a very complex organism. The parts played by microorganisms of the digestive tract, the nutrients themselves and the way the animal organism handles the absorbed nutrients in production of energy and tissue as a fast or a slow gaining individual are quite obscure.

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FIFTY YEARS OF RESEARCH IN AMERICA ON THE NUTRITION OF THE HORSE[1]

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WHEN our present-day knowledge of horse nutrition is compared with that of poultry and other livestock it is safe to state that there has been very little advancement over the last 50 years. The primary reasons for the lack of progress in this field are the same today as at the start of the 20th century—high cost and difficulties of conducting controlled research in equines. During the period when the greatest advances occurred in the field of nutrition of most farm animals, there was a widespread belief that horses had lost their usefulness. This feeling, in part, resulted from the continuous replacement of horses by the mechanization of armies, farms and transport.

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Yet, in spite of modern mechanization, there is still a significant number of horses serving agriculture. What may come as a surprise to many is the increased popularity of the horse as a sport and pleasure animal; large numbers are bred and raised for casual riding and for racing.

Ancestors of the present-day horse were the size of dogs. They apparently inhabited rough terrain and fed on twigs and bushes. In the course of evolution the horse moved to the plains and became a grass eater. There, through a change in diet and genetic selection, horses, as we know them today, evolved (1). Man was quick to appreciate that here was an animal of easy domestication which could serve with apparent minimum dietary requirements. The horse literally was a "hay burner"; and so it has remained with only few changes up to the present day. The average horse survives on simple rations compounded of hays, oats and some corn, with salt as the mineral supplement. Such diets have been a source of wonderment to most animal nutritionists. Herbert (4) in 1859 and Gay (5) in 1914 described procedures for the care and feeding of horses which are still acceptable today.

Nutritionists over the years have lamented the fact that research with

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horses was not only costly but difficult since a single research center seldom could obtain enough horses of the same breed, age and sex for nutrition studies. Most research workers, therefore, were forced to conduct their experiments with inadequate numbers of animals. Others sought cooperation with private owners. Simms (2), for example, borrowed horses from an ice company. In a discussion of one of his feeding trials, he pointed out that by using the horses of such a cooperator he was able to increase the number of animals per group and thus decrease individual and small group variation.

Forages

Regardless of the fact that the horse has survived over the years on simple rations, when plant food sources constitute the main supply of essential nutrients it is obviously of paramount importance that optimum amounts of the various essentials be present. The actual amounts present depend not only on the type of grass but on the fertility of the soil in which the grass was grown, on the season, and on the management and care of the pastures. Where excessive leeching and overgrazing, on one hand, may lower the nutrient content of the forage, proper fertilization and management may increase it.

The reader should not be misled into believing that early nutritionists did not realize that the horse, similar to other animals, had minimum nutritional requirements related to the stress of growth, reproduction and work load imposed. Dunbar (6) in 1925 noted that it was a common practice for farmers to winter their horses on waste forage which happened to be around the farm. Deeming this practice detrimental to the health of the horse, he conducted a controlled feeding experiment in which apparently healthy horses were fed nothing but oat straw. The results showed not only a reduced number of red blood cells but also an inability of the horse to digest feed efficiently, and ample evidence that under such a dietary restriction the animal had to sacrifice his skeletal structure to maintain life.

As evidence accumulated it became apparent that even though the horse would survive on oats and straw the quality of the forages and feed supplements was important (7). Legume hays were found to be distinctly superior to common grass hays (2). In experiments with colts, Hudson (8) demonstrated that liberal feeding hastened maturity, but ultimate development was not seriously affected by the use of limited rations of hay and grain, provided they were supplemented with oat straw. Apparently these horses needed a certain amount of bulk in the diet.

The requirement of the horse for bulk has always been of concern to armies and farmers since rations supplying the proper amount of bulk were difficult to transport efficiently. The importance of the problem stimulated much research in this field. Harvey *et al.* (9) studied the effect of the limited feeding of oats and timothy hay during work on the weights

and nitrogen balance of draft geldings. When limited to 3 lb. of oats and 20 lb. of timothy hay per day, geldings maintained their weight while at rest in stalls. However, under working conditions they suffered slight weight losses. Further, the digestibility of the ration appeared to decrease as the work increased up to a point. No apparent effect on nitrogen balance was observed during the 9-week trial.

Earle *et al.* (10) demonstrated that the minimum amount of roughage required by horses was less than 0.4% of body weight if the ration was otherwise adequate. Their animals seemed to react more favorably to a low rather than a high roughage ration. While research demonstrated that feed storage space could be saved by limiting the roughage intake of horses, compression of complete diets into cakes appeared to be another solution and also a means of providing adequate diets. Exploratory trials (11) demonstrated that the kind of forage used in the mixture was important for determining conditions of temperature and pressure required for the production of satisfactory cakes. Diets containing alfalfa, for example, required a higher temperature and a lower pressure than did those containing timothy hay.

Minerals and Vitamins

Most experiments would indicate that the horse has little need for minerals and vitamins. This raises the question: Is this true because requirements of the horse for dietary essentials are unusually small, or are the technics of measurement confounded or lacking in precision and accuracy?

It is generally accepted that mineral and vitamin deficiencies in animals are closely interrelated, often to such an extent that it is difficult to describe one without taking into account related functions of the others. Many bone disorders seem to be the result of some malfunction of this interrelationship.

Salt has always been considered an important mineral for horses; it is an accepted practice to supply sodium chloride *ad libitum*. A low intake of salt may cause fatigue and exhaustion, accompanied by a further loss of this vital element via the sweat glands. When a salt deficiency is extended over a sufficient period it has also been demonstrated that there is a lowered efficiency in the utilization of proteins (16).

Calcium and phosphorus are two minerals which are especially important in the development of skeletal structure. Kintner and Holt (19) in their classic studies found that the bone disorders they observed in horses were usually accompanied by a low serum calcium to a high serum phosphorus ratio. Schmidt (17) stated that the horse requires a minimum of 1.2 gm. of calcium and 1.2 gm. of phosphorus per 100 lb. body weight; and that these amounts could be greatly exceeded provided the minerals remained in reasonable proportion to one another. There are few studies on the metabolism of calcium and phosphorus in horses. Harvey *et al.* (18) demon-

strated that the retention of calcium and phosphorus by Percheron horses was not influenced by varying amounts of hard work, and that the total elimination of calcium and phosphorus of the horses always exceeded the intake of these minerals during the period of study.

There is very little experimental evidence on the effect of trace elements in the horse diet. Harvey (13), at the University of Minnesota, reports a study covering observations made from 1910 to 1929 on iodine deficiencies in mares. Farm records indicated that the percent of foals raised was less than that of the average breeder. By initiating iodine supplementation without a change in feeding or management the observed losses were significantly reduced. Similarly, Rodenwold and Simms (14) were able to reduce mortality and eliminate clinical signs of iodine deficiency in foals by feeding mares 15 grains of potassium iodide per week during the last half of the gestation period. Zinc is another trace element which has been studied. Graham *et al.* (15) fed pregnant mares and suckling colts as high as 35 gm. of zinc lactate daily for periods of 180 to 400 days without producing any apparent harmful effects.

There are a number of reports which have shown possible interrelationships between minerals and vitamins A and D. Greenlee (20) reported that by replacing one-third the regular army ration allowance for horses with a good quality alfalfa hay there was a marked reduction in disabilities due to skeletal diseases. In this instance both the calcium and vitamin A activity intake were increased. Classic syndromes have been observed in horses fed diets deficient in vitamin A activity. Howell *et al.* (23) observed night blindness, lacrymation, keratinization of the cornea, respiratory difficulties, reproductive disorders, capricious appetite and progressive weakness in horses fed diets deficient in vitamin A. Joint lesions observed in these studies were later shown (24) not to be related to the vitamin A deficiency. Regardless, Howell *et al.* still felt that the observed joint lesions were probably of dietetic origin.

Quantitative requirements of the horse for vitamin A have been given by Guilbert *et al.* (25) in terms of carotene and were set at approximately 5 mg. carotene per 100 lb. body weight per day. In 1945 Squibb (21) observed a general emaciation in horses accompanied by a swelling of the bones of the face and joints of the legs, labored respiration and mucous discharge from the nasal passages, all of which were alleviated by vitamin A therapy and a change in the concentrate ration being fed. At a much later date (22) satisfactory therapy was accomplished on a prized stud which manifested swollen joints, together with a disproportionate serum calcium to phosphorus ratio, by supplementing the ration with a source of vitamin D and bone meal.

The horse, similar to other ruminants, synthesizes considerable amounts of thiamine, riboflavin, pantothenic acid, nicotinic acid, pyridoxine, folic acid and biotin (29). There is, however, evidence that certain B-vitamin supplementation may be of value, especially in deficient rations. Pearson *et al.* (30) have reviewed the B-vitamin requirements of the horse. Studies

on the metabolism of nicotinic acid (31, 32) show that because of synthesis the horse can make normal weight gains on as little as 0.10 mg. nicotinic acid per kilogram body weight per day. While normal diets may contain adequate quantities of pantothenic acid (33), some rations may be low in riboflavin. Equine periodic opthalmia was at one time thought to be related to a riboflavin deficiency (34), but this disease is now known to be caused by a specific infection. Other work (35) shows that varying the dietary intake of riboflavin failed to show any consistent relationship to blood levels.

The role of ascorbic acid in the nutrition of the horse is uncertain (26). Deficiencies may be associated with azoturia (27) and breeding performance (28). However, all workers stress the need for additional data before conclusions may be drawn. For a more complete discussion of the importance of minerals and vitamins in the nutrition of the horse, the reader may wish to refer to Cassius (12).

Use of Chemical Methods for the Determination of the Nutritional Status of Horses

While Hansen and Todd (36) point out that care should be used, since parasitic infestation may influence blood constituent levels, the determination of certain essential constituents of the blood sera has proved valuable for estimating the nutritional status of horses. Irregular blood serum calcium and phosphorus ratios, for example, have definitely been demonstrated to be associated with joint disorders (19, 22).

Pearson and Catchpole (45, 46) in early studies correlated the partition of calcium and inorganic phosphorus between the total and diffusible fractions of these minerals. The report of Nichols (47) indicates that care should be used in expressing calcium, inorganic phosphorus and magnesium values of horse blood in ratios since they may vary independently. Normal levels of serum calcium, phosphorus and magnesium are given by a number of authors (39, 40, 41, 42). The season, age, breed, stage of lactation, pregnancy and altitude all contribute to significant variations in these levels (41, 42, 43, 44).

Blood levels of essentials other than minerals have been observed. In one study (37), normal horses were shown to average 83 mg. % blood sugar content, with a minimum of 66 mg. % in an old horse of poor condition and a maximum of 103 mg. % in a 2-year-old in good condition. Renal threshold was demonstrated by the intravenous injection of 75 gm. of glucose in 15 minutes, which was followed by a rise of 55 mg. of blood sugar and the appearance of traces of sugar in the urine.

Earle (38) demonstrated a striking rise in the concentration of total serum nitrogen following the injection of colostrum in young foals. The author postulated that absorption of immune substances takes place largely with the globulins with which they are so closely associated.

Pearson and Schmidt (33) have shown that the amount of pantothenic acid in blood, which averaged approximately 21 mg. per 100 ml., did not show a constant relationship to dietary intake. Squibb *et al.* (48) have presented reference data on the blood serum levels of total proteins, riboflavin, ascorbic acid, total carotenoids and tocopherols, alkaline phosphatase and vitamin A of native blood horses on green pasture.

While most studies have been on blood, some attention has been given the vitamin content of mare's milk. The ascorbic acid level, for example, was found to be about five times the quantity of that found in cow's milk (49). Data are also given (49, 50) for the thiamine, riboflavin, nicotinic acid, and pantothenic acid content of mare's milk and colostrum.

Space does not permit a review of the work that has been accomplished on the feeding value of cottonseed meal (51), oats and oat by-products (52, 53, 54) for horses, nor the relation of diet to the efficiency of horses for work (55, 56). For additional data, the reader's attention is called to the report of the nutritional requirements and recommended nutrient allowances of the horse published by the National Research Council (57) and to Morrison's *Feeds and Feeding* (58). Due recognition is given to our overseas colleagues who have contributed outstandingly to the field of horse nutrition. Olsson and Ruudvere review much of this work (3).

Summary

Compared to other livestock, only limited research has been done on the nutrition of the horse in the American area over the last 50 years. This has been due not only to the mechanization of armies and farms but also to the high cost and difficulties of running controlled experiments. The research accomplished has done much to define the roughage requirements of the horse. Significant data have been collected on the role of vitamin A and, to a lesser extent, that of a number of B vitamins. Calcium and phosphorus needs have been investigated and the interrelationship of blood levels established. On the whole, most of the nutritional requirements of the horse must still be derived from those determined for other animals.

Major problems of the future will be related to the race horse because of the increased use of the animal for this purpose. The nutrient requirements of a horse raced as a 2-year-old may be higher than for a horse used for pleasure riding or the usual farm work. Training and running an immature animal is a stress factor which no doubt needs a special dietary regimen, a problem which may make this a very interesting area for future research.

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FIFTY YEARS OF PROGRESS IN SHEEP NUTRITION

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IT is most difficult in reviewing the progress that has been made in sheep nutrition to refrain from constantly referring to the progress that has been made in the entire field of animal nutrition. The advances in the nutrition of other species has, in almost every case, contributed to the present knowledge of sheep nutrition. While this review must be limited to work specifically with sheep, acknowledgment is given to the many scientists who have made a contribution to this field although they did not work directly with this animal.

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It is also important to grant acknowledgment to the vast quantity of research work in sheep nutrition over the past half a century that cannot be reported herewith for reasons of limitation. Great progress has been made, but only because of the efforts of many scientists throughout the world.

Status—50 Years Ago

It is well to first establish as nearly as possible our starting point of 50 years ago; otherwise, some may be left with the impression that all we now know has been uncovered since 1908. This is certainly not the case.

The subject of sheep nutrition is an intriguing one, because as Killebrew (1) wrote in 1880:

> "No domestic or wild animals are capable of existing on more different sorts of food. Weeds, grasses, shrubs, roots, cereals, leaves, barks, and even in times of scarcity, fish and meats all furnish a subsistence to this wonderful animal. They will in the great pine forests of Norway and Sweden subsist upon the pungent resinous evergreens through a hard winter. The cultivated grasses of the temperate zone, clover and cereals, are as a matter of course the best food for them, but in the absence of these they will gnaw the barks and crop the leaves of the forests. Among the Laplanders, when all other kinds of food fail, they will eat the dried fish of the people, or the half rotten flesh of the walrus; or in cases of extreme destitution, they will eat the wool off each other's backs."

Some technical research had been conducted before the turn of the century, particularly by German workers. Henneberg *et al.* (2) reported respiration experiments with sheep. They also suggested that sheep require

from 1.0–1.6 lb. of digestible crude protein per 1000 lb. live weight, which is the approximate value today except for the milking ewe and growing lamb. Wolff (3) in 1874 gave the results of digestion trials with sheep and stated that the horse digests about 20% less of the crude fiber than the sheep. Both Wolff and Kellner (4) established feeding standards for sheep that included digestible protein, carbohydrates, and fats. Virtually no information was available on mineral feeding or requirements of sheep. Salt, of course, was recommended. Vitamins were not of concern.

Ingle (5) summarized all published sheep feeding trials reported in Britain between the years 1844 and 1905, numbering 194. He observed that, "Clover hay proved extremely useful not only because of the nitrogenous matter, but also because of its high content of lime compared with phosphoric acid."

Work in this country prior to 1908 concerned such practical phases of sheep nutrition as the following reported by Henry in 1910 (6): Milk production of ewes; composition of ewe's milk; consumption of milk to make certain lamb gains; creep feeding and its affect on lean muscle in the carcass; effect of age on feed requirement; salt requirements of sheep; green forage required by milking ewes; and numerous experiments on feeding sheep different grains, by-products, silages and roots.

Some of the more prominent workers in the field during this period included: Carlyle and Morton of Colorado; Mumford of Michigan; Shaw of Minnesota; Linfield of Montana; Burnett of Nebraska; MacDonald of Oklahoma, and Craig, Humphrey and Kleinheinz of Wisconsin.

Of course, there were other important investigations in nutrition by 1908, specifically in digestion, energy and protein that influenced the knowledge of sheep nutrition at that time. It was somewhat revealing to this author to find that so much important and practical research work had been conducted and that lambs in the feed lot at that time also averaged approximately one-third of a pound of gain daily.

The First 25 Years—1908–1933

With respect to sheep nutrition, this might well be termed the era of energy, protein and feeding trials. It is impossible to specifically review the latter. There was a limited amount of work with minerals and with the identification of vitamin A in 1913, most of the vitamins were known by 1933. Very little work, however, was done during this period on the relationship of vitamins to sheep nutrition. It seems that vitamins were first tested on laboratory animals, then poultry and swine, followed by calves, thus leaving sheep until last.

Energy. Advances were made during this era to determine more specifically the requirements of livestock for energy. While more work was done with some other species than with sheep, it was possible by way of calculations and interpolations to more accurately estimate the sheep's requirement for this important nutrient.

Armsby (7) computed the net energy for maintenance based on a comparison of cattle where 52.8% of the metabolizable energy of roughage and 55% of that of mixed rations was available for maintenance. He concluded that metabolism of sheep per unit of surface was distinctly lower than cattle. He postulated that the thick coat of wool tended to reduce the rate at which heat is lost from the body and that in the course of organic evolution the intensity of metabolism and the rate of heat radiation may have undergone mutual adjustment.

Most of the work on metabolism and heat production where sheep were actually used was conducted by Ritzman and Benedict (8, 9) of New Hampshire. These investigations were based on the use of respiratory quotients in connection with energy production. Their work pointed to a much higher metabolism in sheep than had heretofore been proposed. Their values indicated an order of metabolism in adult and yearling sheep which was more in line with steers.

Another method of arriving at the energy maintenance requirement of sheep at that time was reported by Mitchell *et al.* (10). They combined a slaughter test of lambs with their feeding experiments. A check group of lambs was slaughtered at the start and the remainder at the end of the experiment. In this way they could determine the kind of tissue gained or lost and with the inclusion of a digestion and metabolism trial in their experiment were able to report the results as both total digestible nutrients and as metabolizable energy.

The above together with the work and calculations of Brody *et al.* (11) and Kleiber (12), in large part, form the basis for the present knowledge and recommendation of the maintenance energy requirement of sheep (15). The additional digestible energy above maintenance for lactating ewes as recommended today is based on Brody's (13) figure of 60% net efficiency in milk production. The energy requirements of growing ewe and ram lambs used today are based on modifications of data obtained from the University of Illinois (14).

Protein. The information produced during this period to accurately determine the protein requirement of sheep was limited. Armsby (7) considered non-protein nitrogen of questionable value. On the basis of 0.135 lb. of wool growth daily per 1000 lb. of sheep and 0.41 lb. of digestible true protein per 1000 lb. of body weight to maintain nitrogen balance, he concluded that the two added together gave the daily requirement of 0.55 lb. of digestible true protein per 1000 lb. of sheep. He stated that, interestingly, sheep did not require any more protein than cattle in spite of wool production.

Later during this era, however, the value of crude protein was realized in sheep nutrition. Prior to this time the requirements for protein were based on pounds of digestible true protein per 1000 lb. of live weight.

Today, in comparing the digestible protein requirements of beef cattle and sheep, it is found that the requirements of sheep are somewhat higher

per 1000 lb. of body weight. These digestible protein requirements were published by the National Research Council for sheep in 1957 (15) and for beef cattle in 1958 (16). The former is the source of information occasionally referred to in this paper as the present requirements.

Minerals. The conclusions drawn by Mitchell and McClure (17) regarding mineral requirements at this time were that the only ones needed except in very special cases beyond the suckling state were salt, calcium, phosphorus and iodine.

One of the earliest and most thorough studies of the mineral requirements of sheep was made by Fraps (18) of Texas. He determined the digestibility of potash, lime, phosphoric acid, sulphur trioxide and silica, and reported the following: "The amount of phosphoric acid required in the feeds for a balance would average 1.70 gm. per day and head for sheep weighing about 100 lb. The amount of lime required in the feed for a balance would average 2.8 gm. per day. The amount of magnesia would average 1 gm. per day." These values are slightly below those currently recommended for maintenance.

DuToit *et al.* (19) studied the phosphorus requirement of ewes and found that a change in the dietary phosphorus was rapidly reflected by a changing level in the inorganic phosphorus of the blood. The calcium content of the blood was not affected in spite of the fact that the ratios between calcium and phosphorus in the rations of the groups were 10.5:1 and 0.55:1 which was a 20-fold variation. They concluded it is unlikely that a marked change in the calcium content of the blood can be brought about by varying the calcium of the diet.

Fraser *et al.* (20) and Martin and Peirce (21) also reported work on calcium and phosphorus in the nutrition of the ewe. Auchinachie and Fraser (22) in 1932 demonstrated the beneficial results of adding vitamin D to the rations of feeder lambs under certain conditions.

The critical work of DuToit *et al.* (23) in South Africa showed that neither the addition of cystine nor other forms of sulfur to a basal ration of corn, hay and green feed increased body weight, fleece yield or quality. The amount stored in wool was equal to the intake of cystine. Since 100% efficiency in metabolism was unlikely, they implied that it must be synthesized from some other sulfur-containing dietary constituent.

In 1917, Welch (24) reported woolless lambs resulting from iodine deficiency. A few years later this same author (25) reported his experiments to determine a safe dosage of potassium iodide that could be used as a preventative measure against goiter. He recommended 0.02% iodized salt during pregnancy or a total of 0.2 gm. This is about twice the amount now recommended with continuous feeding.

The status of the knowledge concerning sheep nutrition at the end of this period is best summarized by Mitchell *et al.* (10) as follows:

"The lack of information concerning the nutrient requirements of sheep and their efficiency in the utilization of food nutrients, is mainly responsible for the general

application to sheep of results obtained with cattle, and for the complacency felt in thus transferring bodily to one species information and measurements secured with another. It is high time that experimental investigations on the nutrition of sheep be carried out that will either establish this assumed similarity between sheep and cattle or will permit a separate evaluation of sheep."

The Last 25 Years—1934–1958

Much work was done during this period to determine more specifically the requirement of sheep for various nutrients, especially protein, minerals and vitamins. When one, however, compares the present day knowledge of sheep nutrition with that of other species in this respect it is definitely realized that more research remains to be done.

Protein. Numerous workers have shown a variety of proteins to be equal when fed to sheep. There does appear to be some difference, however, in the biological value of such proteins as egg protein, casein, meat meal and non-protein urea (26, 27). Slen and Whiting (28) found no differences in the value of some of the widely used sources of protein for sheep such as linseed and soybean oil meals or alfalfa in lamb and wool production.

Illinois workers (29, 30) among many others have reported that growing lambs are able to utilize urea but that this non-protein nitrogen is somewhat inferior to the nitrogen of true protein. Urea and other forms of non-protein nitrogen can be used to replace up to ¼ to ⅓ of the protein equivalent of the ration. Growing lambs and mature sheep seem to utilize urea better than fattening lambs, where research is conflicting on its value. In some trials the addition of methionine or sulfur has increased the utilization of urea in rations, but further investigations are needed to fully establish this point.

One very important study reported during this era was that of Loosli *et al.* (31) in 1949. They demonstrated that the 10 essential amino acids are synthesized in large amounts in the rumen of sheep fed urea as the only source of nitrogen.

Klosterman *et al.* (32, 33), Whiting *et al.* (34) and Slen and Whiting (35, 36, 37) conducted rather exacting work to determine the digestible protein requirement of ewes within the last decade. They reported satisfactory production from pregnant ewes receiving as low as 0.10 to 0.13 lb. of digestible protein per head daily. Current recommendations for the digestible protein requirements of sheep are based on these values (15).

Minerals. Much progress has been made in mineral research of sheep nutrition during this past quarter of a century. In 1944, Beeson *et al.* (38) reported the results of their studies on the phosphorus requirement of fattening lambs (figure 1). In an extensive series of feeding trials, these investigators found that a level of 0.12% phosphorus in rations was inadequate, 0.14% borderline, and 0.15% or more of phosphorus was adequate as judged by the rate of gain, efficiency of feed utilization, and maintenance of blood phosphorus levels. From these results, the minimum phos-

Figure 1. Lamb fed a phosphorus low diet and showing deficiency symptoms. (From Idaho Agricultural Experiment Station)

phorus requirement of fattening lambs appeared to be close to 2.17 gm. daily per 100 lb. of live weight. These values were later confirmed by Gallup and Briggs (39) with phosphorus balance studies.

Beeson *et al.* (40) and Keith *et al.* (41) have published their research on the phosphorus requirement of pregnant and lactating ewes. It should be pointed out here that there is a dearth of information in the literature on the Ca:P ratios required by sheep at different stages of production.

Additional research is needed too on the salt or sodium and chlorine requirements of sheep. California workers (42) have reported the use of high level salt feeding as a regulator of protein supplement intake by breeding ewes. Andrews *et al.* (43), among others, have shown the benefit of supplementation with iodine for the pregnant ewe.

A copper deficiency was first designated in 1932 by Bennetts (44) in Western Australia who called it enzootic ataxia and by Stewart of Eng-

land (45) who termed it "swingback." This was because of the helpless swinging or swaying of the lumbar region and hind quarters. Innes (46) changed the name to "swayback" and Bennetts (47) reported in 1937 that it was definitely due to a copper deficiency. This was very soon confirmed by Dunlop and Wells (48). It was interesting to find a footnote in the

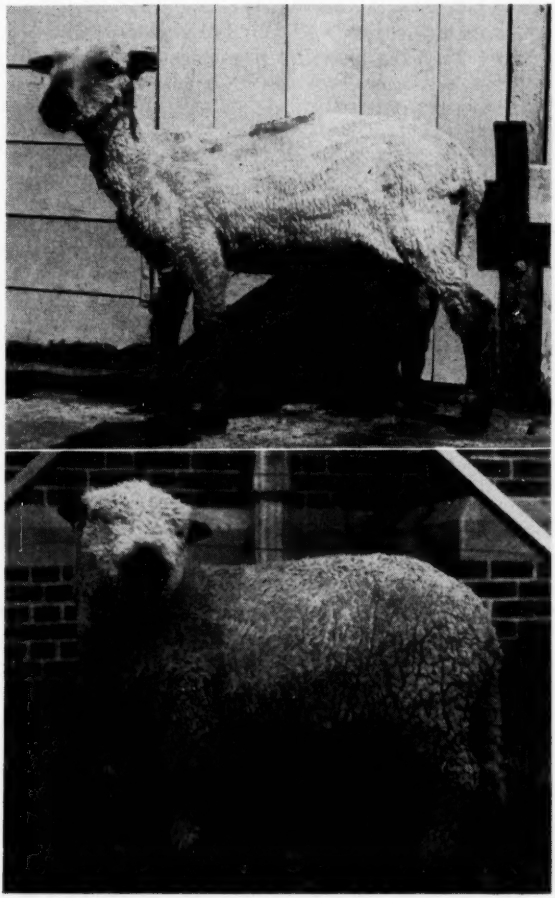

Figure 2. Top. Cobalt deficient lamb—weight 38 lb.—hemoglobin 3.76 gm. %. Bottom. Same lamb after 3½ months of cobalt supplementation—weight 75 lb.—hemoglobin 11.75 gm. %. (From Wisconsin Agricultural Experiment Station)

publication of Dunlop and Wells stating that the original discovery should definitely be credited to Bennetts. This was to settle the controversy at that time regarding the discoverer. No other such acknowledgment was found in reviewing the literature for this paper!

The initial use of cobalt in 1935 to correct a specific nutritional disorder must be credited to Marston (50), Lines (49) and Underwood and Filmer (51) in Australia. Actually, scientists at the Florida Station were working with a cobalt deficiency in 1931, but interpreted it as a copper or iron deficiency (52). They found later that the ferric oxide used to cure the malady was a cobalt carrier and the deficiency could be cured by cobalt alone. Other cobalt deficient areas (figure 2) have been reported on this continent since that time (53, 54).

Numerous workers have established that the sheep is capable of converting inorganic sulfur to protein sulfur (55, 56, 57, 58). These studies also indicate that it is usually more convenient and economical to feed inorganic sulfur as a supplement than organic sulfur compounds. Whiting *et al.* (59) have reported the sulfur requirements of mature ewes.

Beath *et al.* (60) and Moxon (61) have pointed out the relationship between plants containing selenium and the poisoning of livestock called "alkali disease", which has plagued farmers in some areas of this country for 100 years. Toxicity of fluorine for sheep and the symptoms have been reported in some detail by Peirce (62, 63). The earliest mention of a fluorine toxicosis of sheep was by Roholm (64) in 1934. He stated that there exists a description, dating from 1100 A.D., of a disease affecting domestic animals, particularly sheep in Iceland. This disease appeared regularly after volcanic eruptions. The symptoms were similar to fluorine toxicity as shown by Roholm who produced them by feeding lambs excess fluorine.

Goss (65) has demonstrated that high molybdenum is toxic to sheep and will cause depigmentation of black wool. The addition of copper to the ration restores the normal black pigment to the wool. The metabolism of copper, sulfur and molybdenum appears to be interrelated according to Dick (66, 67, 68).

Vitamins. Nearly all of the work with vitamins in the nutrition of sheep has occurred in this past quarter of a century. The first and most extensive work with vitamin A and carotene requirements of sheep was conducted by Guilbert *et al.* (69, 70) of California. They found the vitamin A requirement to be directly related to body weight rather than energy and that it required 200 days to entirely deplete liver storage of ewe lambs previously pastured on green feed, thus proving the tremendous ability sheep have to store this vitamin (figure 3). Work at Washington (71) and Wisconsin (72) have confirmed this ability to store by showing little value of supplementing poor quality roughages fed to wintering ewes that have grazed the previous summer.

It has been well established that the B-vitamins are not required in the ration fed to sheep since the microorganisms of the paunch normally synthesize these in adequate amounts (73, 74, 75, 76, 77). By using a "synthetic" milk diet, it has been possible to study certain B-vitamin deficiencies in the lamb; thiamine and folic acid by Draper and Johnson (78, 79) and riboflavin deficiency by Luecke *et al.* (80). The metabolism of thiamine in sheep has been studied by Austin (81) and niacin by Pearson *et al.* (82). Studies of B-vitamins in the blood and milk of sheep have been reported (83, 84).

Figure 3. Ewe fed carotene low ration during gestation. One lamb was born dead and the other died six hours after birth. (From California Agricultural Experiment Station)

One of the most striking discoveries in the field of sheep nutrition in the past decade was the discovery of vitamin B_{12} in connection with cobalt deficiency. Abelson and Darby (85) indicated in 1949 that radioactive cobalt fed to sheep was incorporated into fecal vitamin B_{12}. Using a chick assay for vitamin B_{12} in rumen ingesta, Hale *et al.* (86) demonstrated that the synthesis of this factor was greatly limited in cobalt-deficient sheep as compared to cobalt-fed sheep. A large quantity of work has given evidence that cobalt deficiency manifests itself as a vitamin B_{12} deficiency and that the cobalt is necessary for incorporation by certain rumen organisms into active substances which are required by the host animal (87, 88, 89, 90, 91, 92). Smith *et al.* (93) in 1951 and Hoekstra *et al.* (94) in 1952 demonstrated the curative effect of vitamin B_{12} administered to cobalt deficient sheep.

Andrews and Cunningham (95) in New Zealand determined the daily requirement of lambs for vitamin D. Duckworth *et al.* (96) showed that lambs have sufficient reserves of vitamin D to protect them against

avitaminosis D for a period of about 6 weeks. Ewer (97) found no difference between the prophylactic efficacy of vitamin D_2 or vitamin D_3 for sheep.

There is more current work in progress on vitamin E than any other vitamin. Its puzzling association with stiff-lamb or white muscle disease has intrigued workers for two decades. Willman *et al.* (98) reported in 1940 that wheat germ meal was the one thing, among many tested, that aided in the prevention of this ailment. These same workers in 1945 showed that insufficient vitamin E was the cause of stiff-lamb disease (99). It was prevented by feeding an oil solution of mixed tocopherols to the ewes and lambs or by feeding an oil solution of d, l-alpha-tocopherol acetate to the lambs at birth. Whiting *et al.* (100) further substantiated this in 1949 and included the analysis of milk for total tocopherols. Michigan workers (101), using a purified liquid diet deficient in vitamin E, have produced stiff-lambs with typical symptoms. These were cured with an initial dose of 500 mg. of d, l-alpha-tocopherol acetate followed by 100 mg. every other day by mouth. More recently, Muth (102) Keith and Schneider (103) and Safford *et al.* (104) have not found vitamin E to be as closely associated with this disorder, thus leaving the role of this vitamin somewhat in question.

The Next Half a Century

There have been new ideas and methods established recently that will contribute much to the field of sheep nutrition in the years ahead. One involves the physical form of using feed. Neale (105) concluded that the feed value of low-grade hay made into alfalfa cubes (pellets) was equal to or better than that of good hay fed by the usual method. This was verified by Cate *et al.* (106) and a number of digestion trials have been conducted comparing pellets with long or chopped hay (107, 108). Blaxter and McDraham (109) in 1956 reported an excellent study on the digestibility of nutrients and utilization of the energy of dried grass when fed in coarsely chopped and pelleted forms. Pellet feeding will require further study of rumination and energy metabolism but its use will expand if for no other reason than the convenience and labor saved.

One of the most controversial subjects in current sheep production concerns antibiotic feeding. The early work of Colby *et al.* (110) in 1950 and Turner and Hodgetts (111) showed a depressing effect on rumen digestion. The effect of feeding chlortetracycline on rate of gain and feed conversion has been variable (112, 113, 114, 115). Likewise, there has not been complete agreement on its protection against enterotoxemia although in most cases it has helped (116, 117, 118). While some of this controversy is the result of many different levels being tested much of it is due to the lack of knowledge concerning the "riddle of the rumen". This could be one of the biggest contributions of antibiotics in that it will stimulate more in-

vestigation into microbial fermentation. Someday it will be possible to control this completely by the ration fed.

New techniques will add abundant information and may well necessitate a re-evaluation of nutrient requirements. Some are in use now, such as an esophageal-fistula cannula for pasture research (119, 120). Others include a re-entrant duodenal fistula (121), *in vitro* studies (122) and radioisotopes (123). Still other techniques will be developed that will make possible a thorough study of the nutrition of the ovum and fetus. Basic research and new methods will eventually uncover the mystery of the hormone-nutrition relationship so that hormones may be used more wisely in sheep production.

One of the most important areas of investigation in the future will be combination studies of sheep breeding and nutrition. Virtually no work of this type has been reported to date. Plant breeding and the nutrition of animals must be included in this combination too.

The sheep industry of this country faces some real and serious problems in its competition with other meats and synthetics in the years ahead. It will require even more progress in research during the next 50 years than in the past if they are to be solved.

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FIFTY YEARS OF PROGRESS IN SWINE NUTRITION

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ABOUT 50 years ago Dawson (1), a Poland China breeder, wrote a book summarizing his "experiences gained during 50 years of breeding and handling hogs". At that time he wrote to each experiment station in the United States asking for details of the best and most economical rations for hogs of various classifications. Twenty replies were received. For weanling pigs, all respondents stressed the importance of good pasture, alfalfa clover or rape. Several Corn Belt stations replied that good legume pasture, corn and water was the most economical combination. In dairy regions, most of the recommended mixtures were skim milk, corn and shorts. Tankage was suggested as a substitute if milk was unavailable. The Mountain States included barley and Illinois included ground soybeans in the suggested mixtures. Slop feeding was a consistent recommendation. Wood ashes, charcoal and salt were recommended as minerals. One person stressed the importance of not overfeeding, especially with protein and especially when the pig was young.

L. E. Hanson

In 1908 Kellner (2) wrote, "With regard to the feeding of young pigs there is not, unfortunately, any investigation which throws light upon their requirements, and so the experience of practice has to be relied upon". Kellner stressed the importance of supplying sufficient protein to growing pigs, the deficiency in calcium of several common feedstuffs and the need for calcium supplementation. He stated that phosphorus supplementation was needed only with certain feedstuffs and estimated the daily requirement of the pig at 12 gm. each of lime and phosphoric acid.

Virtually all of the feedstuffs commonly used today were available by the same name for feeding in 1908 (3). Most of them had been fed in some form of experiment in Canada, Denmark, Germany, Great Britain or the United States. The most notable exception is soybean oil meal, which is primarily a development of the past 30 years in the United States.

The first research reports dealing with swine given at the Society of Animal Production meetings were presented in 1913. Forbes (4) reported that metabolism experiments indicated that the serious deficiencies of corn were first calcium, second phosphorus and third nitrogen. Evvard (5)

listed the deficiencies of corn as low in protein, inferior quality of protein (citing recent work of Osborne and Mendel), especially deficient in calcium and an "acid ash". He presented data from a 3-year study at Iowa which showed clearly that supplementing the corn ration for gilts or yearling sows with meat meal, legumes or linseed oil meal resulted in larger, stronger pigs at birth. Meat meal was the most effective. King (6) reported that ground corn was 6% more efficient than shelled corn for heavier hogs and cited 18 experiments at Wisconsin which also showed the same relative difference. The difference due to grinding was much less for small pigs.

During the past 50 years, thousands of papers and reports have been published on subjects of interest to those engaged in swine research and to the swine producer. Time and space limitations make it impossible to review all of the interesting developments. Therefore the review will be restricted to those items which, in the opinion of the author, have had the greatest impact on swine production in the major swine producing areas of the United States. Of particular significance are: 1.) The recognition of "quality" in protein which has led to reasonably satisfactory estimates of the amino acid content of feedstuffs and requirements of young pigs. 2.) The development of the soybean crop from insignificant proportions to the major source of high quality protein for swine rations. 3.) Studies in mineral nutrition and especially the determination of calcium and phosphorus requirements; the solution of iron-deficiency anemia and goiter. 4.) The discovery of vitamins, their isolation and synthesis, and studies which led to estimates of requirements of pigs; the commercial development of low cost vitamin supplements. 5.) The discovery of the value of antibiotics and other antibacterial agents. 6.) Changes in methods of feeding.

Protein Quality and Requirements

Amino acids. More than one-half of the various amino acids which result from the hydrolysis of proteins were discovered in the nineteenth century (7). Among those which we classify as essential for growth of the pig only two, methionine and threonine, are discoveries of the past 50 years. Block and Mitchell (8) reviewed the developments that led to the concept of essential and non-essential amino acids in nutrition. They credited the pioneer investigations of Willcock and Hopkins, Abderhalden, Osborne and Mendel, McCollum and the later studies of Rose and of Almquist for establishing this concept.

In 1912 McCollum and Steenbock (9) showed that zein was used by the pig for "repair" of the losses due to endogenous metabolism, but produced no growth. Casein increased body protein 20 to 25%. The authors stated, "Repair processes are shown to be of a different character than those for growth". Studies by Osborne and Mendel reported in 1914 (10) showed that the deficiencies of certain proteins (including zein) for growth could

be corrected by the addition of missing amino acids. Subsequent work by many others soon led to the realization that the value of a protein in the nutrition of the pig is related to its amino acid composition. In 1926 Mitchell (11) stated that "The protein requirements of animals are still stated in terms of a given weight of digestible food protein per unit weight of animal or of product, a survival of the time when chemical differences between proteins were unknown or unappreciated". He commented that while this "is incongruous with present-day knowledge no other statement is possible because of the fact that precise information concerning the values of feeds and mixtures of feeds is not at hand". As the ideal solution of the problem of stating protein requirements Mitchell stated, "Possibly a protein requirement ultimately can be expressed in terms of the amounts of different indispensable amino acids, functioning either singly or together, as its components".

Grindley (12) stated that he and his coworkers were the first to publish data on the quantitative determination of amino acids in feeding stuffs. He also referred to Nollau's (13) work and indicated that their results were not in complete agreement. Both used the Van Slyke method in their determinations.

The adequacy of various feedstuffs in supplying the needed amino acids deficient in corn and other grains were studied in innumerable swine feeding tests over a period of many years. These experiments provided useful information, but they did not answer the specific basic questions regarding amino acid content of feeds or requirements. Through the work of many people improved methods for the determination of amino acids in feedstuffs were developed. An important advance was made in 1941 (14) when the technique of chromatography was introduced and in 1943 when microbiological methods of assay were introduced. Other methods have been developed also (14). These developments led to many studies of the amino acid content of feeds.

Block and Mitchell (8) reported the approximate amino acid composition of a variety of proteins and feedstuffs in 1946. A table of estimated amino acid values for common swine feeds was published by the National Research Council in 1953 (15). Lyman *et al.* (16) published a summary of many years of their work on a wide variety of feedstuffs in 1956, and Morrison (17) also published estimates of the amino acid content of feedstuffs, based on published reports from many sources.

Modern advances in amino acid nutrition began in 1930 with the classical studies of the amino acid requirements of rats by W. C. Rose and Associates (18). These were followed by studies with chicks which showed that the chick required the same amino acids as the rat, plus glycine (19).

Studies of the specific and quantitative amino acid requirements of the pig have been reported within the last decade, and show that the young pig requires in the diet the same 10 amino acids as the rat. Most of this research has been done by workers at Cornell, Purdue and Illinois, though

others have contributed as well. Recent summaries by Cunha (20) and Becker (21) provide excellent bibliographies regarding these studies. Thus we seem to be approaching the "ideal solution" of the protein problem suggested by Mitchell (11). However, much remains to be done because the data on requirements pertain only to young growing pigs.

Protein Requirements. The crude protein or digestible crude protein requirements of pigs based on specific combinations of feeds were studied by many workers during the period 1925–45 (22). Crampton's (22) studies were based on barley rations, the others on corn. Crampton pointed out the basic limitations of stating a minimum protein requirement in view of the lack of information with respect to the amino acid complex of a given ration.

Following the discovery of vitamin B_{12}, Cunha *et al.* (23) reported that the use of an "APF" supplement apparently reduced the protein requirement of the pig, and suggested that recommended protein levels might need revision. Catron *et al.* (24) and Hoefer *et al.* (25) did reevaluate crude protein needs of growing pigs fed corn rations and recommended lower levels. These findings have been confirmed by several others (26, 27, 28). It is now clear that in the older studies with corn rations the supplemental feeds added to produce the higher protein levels were also increasing the vitamin content of the rations, especially B_{12}. Today a ration based on corn and high quality soybean oil meal, properly supplemented with minerals and vitamins, need not contain more than 14–16% crude protein for weanling pigs, nor more than 12% protein for pigs weighing from 100 to 200 lb. and fed in dry lot.

Evans (29) studied protein metabolism of sows, as affected by calcium levels. The classical studies of Mitchell *et al.* (30) on the deposition of nutrients in the uteri of pregnant gilts have been the basis for practical recommendations regarding not only protein but energy and mineral elements as well. Further studies are needed, since the Illinois work was done prior to 1931.

Soybean Oil Meal. Fifty years ago soybeans were a minor crop and apparently grown primarily in the Gulf States. Henry (3) stated in 1910, "No other plant in the United States grown so little at this time as the soybean is so full of promise to agriculture, especially to animal husbandry. Soybean meal [ground soybeans] should always be used in combination with other grains, and the meal from which the oil has been expressed should prove superior to the ground seeds". These were prophetic statements indeed.

Soybean oil meal was first produced in the United States by the expeller process in 1915. The industry grew slowly and prior to 1930 less than 50,000 tons of meal were produced annually. During the following decade average production increased to 482,000 tons. In 1942 the tonnage of soybean oil meal was equal to that of cottonseed meal or milk products (dry basis) and by 1944 the tonnage was greater than the combined tonnage of milk products and cottonseed meal (31).

Increases in soybean production, and hence soybean oil meal production have continued up to the present time so that in 1956–57 more than 7,000,000 tons were produced (32). This was about half of the total of all high protein feedstuffs produced in the United States.

In 1905 Humphrey and Fuller (3) found that ground soybeans were superior to wheat middlings for pigs, but the feeding of the beans produced soft pork. Skinner (33) of Indiana reported the same year that ground soybeans and corn produced slightly faster and more efficient gains than corn and middlings, corn and tankage or corn and linseed oil meal. It is

Figure 1. "Hogs being fattened on soybeans and corn during the winter season." Date, 1920. (From Univ. of Minn. files.)

interesting to note that the pigs fed corn and soybeans required only 311 lb. feed per 100 lb. gain (initial weight 55 lb., final weight 161 lb.). Another early method of feeding soybeans is shown in figure 1.

In 1917 Osborne and Mendel (34) demonstrated that moistened, ground soybeans cooked over a steam bath for 3 hours at 80–90° C. promoted normal growth in rats, whereas raw soybeans did not. They commented that the vitamin content plus the protein of high physiological value "lends a unique significance to the use of soybeans as a food". Many years later Bowman (35) and Ham and Sandstedt (36) found that unheated soybeans contained a trypsin inhibitor which was destroyed by proper heating, thus apparently explaining the increase in feeding value due to heating. Numerous studies, reviewed by Liener (37), indicate that the change in nutritive value of the soybean, brought about by heating, is due to several factors. Overheating has been shown to be detrimental to the nutritive value of the soybean as well as underheating.

Studies at Wisconsin (31) with rats, at Cornell (31) with chicks and at Ohio (38) with swine (in cooperation with soybean processors and equip-

ment manufacturers) demonstrated the importance of time, temperature and moisture in processing soybeans. These studies were of particular importance in establishing the foundation for the efficient commercial processing of the high quality soybean oil meal produced today.

A comprehensive summary of soybean and soybean oil meal research with swine has been published by Robison (38). This bulletin includes data obtained at the Ohio Station from 1916 to 1950 and illustrates very well the changes and progress which were made in the development and efficient use of the soybean for swine, over that period of 34 years.

Recent studies at Cornell (39) and at Illinois (40, 41) and many other stations, show clearly the high value of properly processed soybean oil meal as a source of protein (amino acids) for swine. In the Cornell studies, methionine supplementation did not improve the growth of pigs fed a corn-soybean oil meal basal diet, though methionine is generally considered the first limiting amino acid in soybean oil meal. The Illinois studies showed soybean oil meal to be superior as a source of protein to fish meal and to meat and bone scraps. It is indeed fortunate that our major source of supplementary protein for swine, soybean oil meal, has such an excellent distribution of amino acids.

Minerals

Calcium and Phosphorus. Recognition of the importance of calcium in animal rations dates back more than 100 years (42). That calcium and phosphorus are required by the pig was demonstrated by European workers in the last half of the 19th century. In 1890 Henry (43) reported two experiments in which the value of wood ashes and bone meal were compared as supplements to corn. These sources of minerals not only increased feed efficiency but doubled the breaking strength of the thigh bones. In 1908 Burnett (44) reported experiments conducted to determine the value of various feedstuffs as supplements to corn. His studies showed that the rations did not affect the average length, circumference or volume of the bones measured. Thickness of the bone wall and breaking strength were markedly increased by the feeding of bone meal, tankage or skim milk. Bone meal was the most effective. Burnett presented x-ray photographs of some of the humeri. This appears to be the first experiment with swine in which this technique was employed.

The following year Hart *et al.* (45) reported that pigs fed rations low in phosphorus developed difficulty in locomotion. In view of the present interest in availability of various sources of phosphorous it is noteworthy that the Wisconsin workers planned their experiments to study the then controversial question of whether inorganic phosphates were as useful as organic sources. They found that inorganic phosphorus was well utilized by the pig and they estimated the phosphorus requirement of the 50 lb. pig at 4 to 5 gm. daily, with a minimum of 3 gm. Forbes (46) also demon-

strated that corn is particularly low in calcium, and a few years later Forbes *et al.* (47) showed that pigs fed rations containing milk and meat meal stored 9 to 10 times as much calcium as pigs fed exclusive grain rations. The lack of calcium in grain rations was also stressed by Hart, Steenbock, and Fuller (48) and they found that the addition of calcium to a calcium deficient ration increased the retention of phosphorus.

Following the discovery of vitamin D many studies were made to assess the calcium and/or phosphorous requirements of growing pigs. Such studies were reported from Denmark (49), Sweden (50), England (51), Ohio (52), Illinois (53), and Kansas (54) between 1933 and 1941. The minimum calcium requirement for the young pig was found to be near 0.4% and the phosphorous requirement approximately 0.3% when the ration contained adequate vitamin D (Kansas Studies). The Illinois data were in good agreement with these findings and indicated that for older, heavier pigs the calcium and phosphorus requirements were lower. In 1955, a thorough restudy of calcium and phosphorous requirements was reported by the Iowa Station (55). They found the optimum calcium and phosphorous requirement to be 0.8% and 0.6%, respetcively for pigs weighing from 25 to 100 lb. and 0.7% and 0.5%, respectively for pigs up to 200 lb.

In 1932 Hogan (56) reported that the calcium content of brood sow rations should not be less than 0.4%.

Zinc. The recently recognized problem of parakeratosis in swine has made many nutritionists aware of the hazards of feeding excessive levels of calcium to young pigs. Studies by Tucker and Salmon (57) showed that zinc additions to the ration of pigs affected with parakeratosis brought about a prompt recovery. These findings were soon confirmed by many others (58). It is clear from these studies that the pig has a requirement for zinc and that calcium and zinc are interrelated. High calcium levels increase the requirement of zinc. However, the complete elucidation of this interesting problem awaits further research.

Magnesium, Manganese, Potassium, Sulfur, Cobalt. That the pig requires magnesium was reported by Purdue in 1957 (59). Arkansas, Pennsylvania, and Wisconsin workers have shown that the pig requires manganese, and California and Wisconsin have demonstrated the pig's requirement for potassium. The pig's requirement for sulfur is met if the ration is adequate in sulfur containing amino acids. North Dakota, Cornell, and Iowa workers have reported increased growth in pigs when cobalt was added to certain types of diets. No one has succeeded in demonstrating a need for added cobalt in swine rations which are adequate in vitamin B_{12}. The studies cited above have been reviewed by Cunha (20). Swine rations based on the usual variety of feedstuffs, and well balanced in other respects, are generally considered to be adequate in these elements.

Iodine. The problem of simple goiter in man and animals dates back hundreds of years. The first indication that iodine deficiency might be responsible dates to 1830 (60). Studies with iodine in the latter half of

that century; the discovery of iodine in the thyroid gland in 1895 (60) and the isolation of the hormone, thyroxine in 1919 (60) led to rapid progress in the understanding of goiter.

Spurred by heavy losses in newborn pigs (hairless pigs) the Montana Station started a series of studies of the malady which were reported in 1917 by Smith (61) and by Welch (62). Assays of thyroids from normal pigs and from hairless pigs showed that the glands of hairless pigs were abnormally large; had very low iodine content in comparison with normal glands; and the degree of hairlessness varied inversely with the iodine content of the thyroids. The feeding of 2 grains of KI daily per sow during gestation doubled the iodine content of the fetal glands. The feeding of 5 grains KI daily per sow from 2 weeks after breeding to farrowing resulted in strong, vigorous, normal pigs. Hart and Steenbock (63) confirmed the Montana findings that the hairless pig malady was associated with a hyperplasia of the fetal thyroid, and stated that it could be corrected by the feeding of 10 gm. of KI per 100 lb. of feed to the sow during gestation. They did not recommend the general use of iodine but rather its use in regions and on farms "where hairless pig production is endemic".

Other studies confirmed these early findings, iodized salt was developed and later methods of stabilizing the iodine content of such salt were evolved. Today iodine deficiency is recognized as an area problem, and the principal deficient areas in North America are the Great Lakes region, the Pacific Northwest, and Western Canada. However, the use of stabilized iodized salt or trace mineralized salt (including iodine) appears to be used in most livestock rations throughout the United States.

Iron and Copper. Fifty years ago an author of a book wrote: "*Thumps.* This is a very common ailment of pigs. The exciting causes of the disease are lack of exercise and irritation to the stomach and intestines resulting from irritating feed, over-eating, and changes in the diet. This irritation to the gastric and intestinal nerves results in secondary irritation to the nerves that go to the diaphragm, and spasmodic contractions of this muscle occur. The treatment is both preventive and curative. Preventive treatment in young pigs consists in feeding the mother a proper diet and giving the pigs good care and plenty of exercise." Generally, most writers believed *thumps* to be due to a lack of exercise and improper feeding of the sow. This seemed perfectly logical because the larger, faster gaining pigs became anemic first and in general appeared to be overfat. That exercise was of indirect benefit in many cases was undoubtedly due to the fact that the pigs thus had an opportunity to eat some dirt, dropped from the caretaker's boots.

McGowan and Crichton (64) were apparently the first to report the cause of iron-deficiency anemia in suckling pigs. They observed anemia in pigs farorwed by sows confined on concrete floors and described the symptoms as well as the post mortem findings. They fed sows nursing anemic

pigs large doses of ferric oxide and brought about marked, though incomplete recovery of the anemic animals. In a subsequent study of 2 split litters one sow was fed 40 gm. of ferric oxide daily. Most of the pigs nursing this sow did not become anemic whereas the control pigs were severely affected. They stated that the feeding of iron probably did not increase the iron content of the milk. They noted that the pigs probably got additional iron by consuming some of the feed spilled on the floor and by eating the sows feces.

Elvehjem *et al.* (65) showed that the feeding of ferric oxide or ferrous sulfate to goats at 5 times the usual iron content of the ration did not increase the iron content of goat milk. Doyle, Mathews, and Whiting (66) observed anemia in pigs kept indoors and showed that the feeding of ferric lactate, cod-liver oil, yeast or orange juice to the sows did not prevent the disease. Further studies by the Wisconsin Station (67) revealed that copper was needed as well as iron to cure anemia in rats, and in 1932 (68) they demonstrated that copper is also necessary for hemoglobin formation in the pig. Teague and Carpenter (69) have confirmed the need for copper in hemoglobin formation in the pig and also produced an unusual condition of the legs in the deficient animals.

Studies by Hamilton *et al.* (70) and by Hart *et al.* (71) demonstrated that the feeding of iron and copper to the sow would not prevent anemia in the nursing pigs. The Wisconsin workers showed that the feeding of iron alone to suckling pigs stimulated hemoglobin synthesis as well as iron and copper, but pointed out that copper additions might be necessary under very restricted conditions.

Other studies demonstrated that anemia could be prevented by providing sod for the pigs to eat, by swabbing the lactating dam's udder once daily with a saturated solution of ferrous sulfate or by dosing the pigs with iron, individually by mouth. In the latter case weekly treatments were generally recommended. Careful studies by the author (72) showed clearly that daily swabbing was much more effective than weekly treatments of individual pigs.

Despite all of the research done on the anemia problem in the 1920–30 period, the author believes that anemia in pigs on the farm has been one of the greatest problems in swine production during the past 20 years. Perhaps this was due to the fact that anemia is an insidious disease and much damage is done before the producer is aware of the problem.

Perhaps the development, by the British, of an injectable iron compound will finally solve the anemia problem. Kernkamp (73) reviewed the British studies with this compound and presented the first American data on its use. Several Stations are studying its value at the present time.

Iron and copper nutrition has not been a problem in swine production, except in suckling pigs. There has been recent interest in the feeding of copper to weaned pigs, but the results of such studies are inconclusive.

Vitamins

It was recognized in the nineteenth century that protein, carbohydrates, fat and ash did not supply all of the needs of a growing animal. Hopkins, in 1906, suggested the term "accessory food factors" for these unknown substances and Funk coined the word vitamine in 1912 (42). Rosenberg (74) has provided a chronology of the developments concerning each of the vitamins up to 1943.

Vitamin A. In 1913 McCollum and Davis (75) and Osborne and Mendel (76) furnished definite proof for the existence of vitamin A and its specific function in growth. The following year the latter workers demonstrated its presence in cod-liver oil, and since 1920 numerous workers have studied its importance in the nutrition of the pig. In 1919 Steenbock noted the relationship of yellow color in many vegetable foods with vitamin A potency, and in 1929 Moore produced proof that the animal body transforms carotene into vitamin A (42).

The discovery that yellow corn has vitamin A value whereas white corn contains little or none was reported by Steenbock (77) in 1919 and by Steenbock and Boutwell (78). This discovery led to investigations by Morrison *et al.* (79) of the feeding value of white and yellow corn fed in dry lot. These investigations clearly demonstrated the inferior quality of white corn in rations which are low in vitamin A. This finding was confirmed by workers at Nebraska (80), Iowa (81), Illinois (82), Kansas (83), West Virginia (84) and North Carolina (85). Today white corn is grown primarily by a few farmers for special uses in industry. Its lack of vitamin A value was undoubtedly a factor in its near disappearance from the farm.

The effects of vitamin A deficiency on swine have been studied and described by several workers. However, in some of the studies the rations fed were undoubtedly deficient in other vitamins which were unknown at the time of the study. In 1928 Hughes *et al.* (83) reported the detailed results of a 7-year study of vitamin A deficiency in swine. They found that when pigs were placed on the A deficient ration (white corn tankage and bone ash) immediately after weaning the average time required for the first symptoms to develop was 219 days. The symptoms in the order in which they appeared included restlessness, characteristic posture, incoordination and spasms. Eye lesions were minor, but impairment of vision occurred early. Longwell *et al.* (86), Hostetler *et al.* (85) and Foot *et al.* (87) found a more severe impairment of vision in their A deficient pigs. Lund (88) studied the effects of A deficiency on metabolism.

The requirement of the pig for vitamin A has been studied by many workers from 1922 to the present. Nelson, Heller, and Lamb (89) concluded that the requirement of pigs is similar to that of rats and less than that of rabbits. Two years later Orr and Crichton (90) concluded that the requirement of the pig for vitamin A is so low "that during the usual fattening period, that is between weaning and slaughter, there is little likli-

hood of pigs suffering from vitamin deficiency under practical feeding conditions". Dunlop (91) pointed out that some of the rations commonly fed in England were deficient in vitamin A. In a series of carefully controlled experiments Guilbert *et al.* (92) studied the carotene and vitamin A requirements of sheep and cattle as well as swine. They reported the minimum requirement of swine as 25–39 mcg. and 4.4–5.7 mcg. per kg. body weight of carotene and vitamin A, respectively. For significant storage and optimal dark adaptation the requirements were found to be higher, 12 mcg. vitamin A or 125 mcg. carotene. The vitamin A requirements of baby pigs have been reported recently by the Cornell (93) and Iowa (94) Stations.

Other studies have shown that the pig fed an excess of the vitamin can store the excess for possible future needs (82). Over the years the principal sources of provitamin A in swine rations have been yellow corn, legume pastures, legume hay and artificially dehydrated alfalfa meal. Fish oils have been used extensively as a source of A in manufactured feeds. A relatively recent development has been the production of high potency, dry, free-flowing stabilized vitamin A supplements.

Vitamin D. In 1916 McCollum and Kennedy (95) proposed the term fat-soluble A for the growth factor found in butter and other fats and water-soluble B for the anti-beriberi factor. The proof that A and D were different vitamins was furnished by McCollum *et al.* (96) in 1922.

Hart and McCollum in 1916 (97) found that the feeding of alfalfa hay prevented stiffness in pigs. Hart and Steenbock (98) raised the question as to the importance of roughage in the prevention of stiffness. On feeding a basal diet low in vitamin D, supplemented with paper they produced stiffness in pigs. This was proof that the value of the hay in preventing stiffness was not due to its high fiber content. The value of alfalfa hay in the prevention of rickets was also reported by the Ohio Station (99). In 1922 Maynard (100) reported stiffness and paralysis in pigs and a subsequent study showed that cod-liver oil and added minerals produced marked improvement in pigs suffering from stiffness.

That sunlight is a factor of economic importance in the production of swine raised under confined conditions was concluded by Steenbock, Hart and Jones in 1924 (101) (Hess of Columbia and Steenbock and Associates of Wisconsin reported in 1924 that certain foodstuffs could be made antirachitic by exposure to ultra-violet light (42)). The same year Zilva *et al.* (102) reported curing rachitic pigs by allowing them access to sunshine. Other studies on the value of sunlight for pigs which were fed rations deficient in minerals or vitamin D, or both, were reported by many investigators (Bohstedt *et al.* (103); Sinclair (104); Loeffel *et al.* (105); Lund (106); Dunlop (107)). Shaw (108) found that sunlight which had passed through ordinary window glass was of little if any value.

The use of cod-liver oil as a specific for rickets was known long before vitamin D was discovered. Following the discovery of D the use of cod-liver oil in rations for pigs was studied by many investigators in the U. S.,

Canada, England and elsewhere (1925–1939). In general these studies showed that the benefits derived were more or less inversely proportional to the adequacy of amounts and proportions of calcium and phosphorous, and to the presence of other sources of vitamin D in the ration.

The general symptoms of rickets in pigs are similar whether the deficiency is due to calcium, phosphorous or vitamin D. However the blood picture varies according to the specific cause and bone pathology may also vary according to the dietary factor involved. Symptoms of the disease were described by Elliott *et al.* (109), Maynard *et al.* (100), Zilva *et al.* (102), Bohstedt *et al.* (103), Loeffel *et al.* (105), and by others.

The pig's need for dietary sources of vitamin D obviously is dependent on several factors. Studies have shown that the level of calcium and phosphorous, the ratio between them and the presence or absence of direct sunlight affect the dietary requirement. Johnson and Palmer (110) showed that white pigs apparently store more of the vitamin than colored pigs (if previously exposed to sunlight), but that vitamin D is required even when the ration contains 1.0–1.1% Ca and 0.6–0.7% P. The colored pigs became rachitic too—it merely required more time. Bethke *et al.* (111) estimated a requirement of 90 I.U. vitamin D per lb. of total ration. Vitamin D_2 is as effective for pigs as vitamin D_3.

On the basis of studies by Crampton and Ashton (112), and others, it appears that there are breed variations, perhaps strain variations among pigs regarding requirements for this vitamin.

The only common feed source of vitamin D is sun-cured forage and some fish meals and these plus sunlight have been the principal sources of D for pigs for many years. Fish oils and irradiated yeast have also been used. Fortunately, the cost of vitamin D today, as supplied by irradiated yeast, is so low (one to two cents per ton of feed) that its use adds very little to the cost of pig production, even if no benefit is derived.

Vitamin C. In 1928 Hughes *et al.* (83) reported that swine do not need vitamin C in the diet for growth and reproduction. In 1950 Braude *et al.* (113) showed that the pig could synthesize its metabolic requirement of this vitamin, from birth to maturity.

Vitamin B Complex

Thiamine, Riboflavin, B_6, Nicotinamide and Pantothenic acid. From the water-soluble accessory growth factor named water-soluble B by McCollum and Kennedy (95) in 1916, there has grown a whole host of specific vitamins, generally labelled today as the vitamin B complex. Lepkovsky (114) has reviewed the early history that led to the distinction between the antineuritic factor (thiamine) and the heat stable factor (G), and the separation of the latter into riboflavin, pyridoxine (B_6), nicotinic acid and pantothenic acid. Ellis (115) reviewed the vitamin requirements of swine in 1946; Carroll and Krider (116) included a bibliography on swine in

their book published in 1956, and Cunha (20) published an extensive bibliography regarding vitamins in swine nutrition, in 1957. The Committee on Nutrition of the National Research Council also published an extensive compilation of the vitamin content of feeds and the vitamin requirements of swine in 1953 (15). Therefore, in the interest of time and space this review will be limited.

Generally, studies concerning vitamin requirements of swine have followed studies with chicks, rats, and/or microorganisms for several very practical reasons. Most of the studies with swine concerning thiamine, riboflavin, B_6, niacin and pantothenic acid were made after the vitamins were available in crystalline form or in known potencies. Thus these studies are concentrated during the past 20 years. The isolation dates according to Rosenberg (74) are: thiamine, 1926; riboflavin, 1933; B_6, 1938; pantothenic acid, 1939. Nicotinic acid was isolated in 1911 (114).

The studies have shown that the pig has a dietary need for each of the vitamins listed above. While it is not possible to list all of those who contributed to our knowledge, it seems appropriate to mention the pioneers who made many contributions in this area. Chick *et al.* (115) of England (1938) pioneered in the study of niacin deficiency and in studies of pantothenic acid and B_6. Hughes of California (115), from 1939 to 1943, used a purified diet and reported symptoms of deficiencies and estimates of requirements for each of the vitamins. Wintrobe *et al.* (115) in the Medical Schools of Johns Hopkins and the University of Utah have contributed much basic information to our knowledge of swine nutrition not only of the B vitamins but of minerals as well. Ellis *et al.* (15) of the U.S.D.A. made significant contributions in the early studies of thiamine, pantothenic acid and B_6 and estimates of vitamin content of feedstuffs. Following the early work, contributions to our knowledge of the B vitamins in swine nutrition have come from many investigators, particularly those at Michigan, Illinois, Iowa, Washington, and the U.S.D.A. Stations. The author reviewed many of the recent studies, particularly those with baby pigs in 1957 (58).

Thiamine and B_6 deficiencies are not likely to occur in practice because the commonly used feedstuffs are good sources of these vitamins. Riboflavin and pantothenic acid deficiencies can and do occur, particularly when pigs are raised on concrete. The cereals, especially corn, are relatively poor sources of both vitamins and many of the supplemental feeds are relatively poor sources at the levels fed. High quality alfalfa meal is usually a good source. Good legume pastures are also excellent. The author has produced pantothenic acid deficiency in growing pigs with a corn ration which was supplemented with 5% alfalfa meal and a mixture of equal parts tankage, sardine meal, soybean oil meal and linseed oil meal (18% protein ration).

Niacin (preferable nomenclature, nicotinamide, 42) deficiency should not occur, on the basis of published values of the common feed stuffs. The

known tryptophan deficiency of corn protein, the interrelationship between tryptophan and niacin and problems of availability of the vitamin are probably involved here, because niacin deficiency has occurred when rations based on corn were fed. To the author's knowledge niacin deficiency has never occurred when barley was the cereal fed.

Choline, Biotin, Folic acid, Inositol, p-Aminobenzoic acid. Choline has been shown to be required in the diet of the baby pig when the ration contained 0.8% methionine (117). Choline and methionine are interrelated in that both are involved in the phenomenon labelled transmethylation. When the Illinois workers (118) increased the methionine content of the diet they could not produce a choline deficiency. Choline deficiency is considered unlikely in the common rations of older pigs. Biotin is synthesized by the weanling pig in sufficient amounts to meet his needs (119). Folic acid deficiency has been produced only by the simultaneous feeding of an antagonist or a sulfonamide (20). Inositol and p-aminobenzoic acid deficiencies could not be produced by the Illinois workers (120).

Vitamin B_{12}. The story of the work that led to the isolation of this vitamin is one of the most interesting in the entire history of nutrition. Ruth Woods (121) has reviewed that history from its start in 1926, with the report by Minot and Murphy on the effectiveness of liver therapy in the treatment of pernicious anemia, to the isolation of B_{12}, reported by Rickes and coworkers of Merck Laboratories on April 16, 1948, and by Smith (England) one week later. Subsequent studies resulted in the commercial synthesis of B_{12} by microbiological procedures. Studies of various early B_{12} (APF) concentrates in rations led to the recognition of the value of antibiotics in swine rations.

As is well known, soybean oil meal figured prominently in many of the studies prior to the isolation of B_{12} and in subsequent studies. The discovery of B_{12}, and its commercial availability, has increased the usefulness of soybean oil meal in rations for swine and poultry to a highly significant degree. Merck and Co. (122) has recently published a monograph on vitamin B_{12} in animal nutrition, with appropriate bibliographies.

The studies reviewed show that B_{12} is required by the pig for growth and reproduction. Crude sources of B_{12} are generally added to swine feeds today.

Antibiotics and Other Antibacterial Agents

Antibiotics. The first report that an antibiotic had a "growth stimulating" effect (in chicks) was published by Moore *et al.* (123) in 1946. This report largely went unnoticed. Three reports in the early months of 1950 by Jukes *et al.* (124), Luecke *et al.* (125) and Carpenter (126) afforded evidence of the effectiveness of specific antibiotics in swine feeding. Since that time a deluge of papers have been written reporting the results of various experiments. Braude *et al.* (127) reviewed the studies reported from 1950 to

1953. Jukes (128) cited more than 400 papers (studies with many kinds of animals and man) in a monograph on antibiotics published in 1955. In view of these extensive published bibliographies it seems advisable to merely summarize the past and present status of the antibiotics.

Antibiotics were quickly accepted by swine producers following their introduction. According to Welch and Marti-Ibanez (129), 490,000 lb. of antibiotics were used in feeds for all livestock in 1954 alone. The results obtained by feeding these drugs to swine on many farms and in many experiment stations bordered on the miraculous. Prior to the advent of the antibiotics, diarrhea in young pigs in many station herds was a constant problem. Reports of experiments from many stations almost invairably carried footnotes to the effect that a number of pigs from one lot or another were removed from the test due to unthriftiness.

The beneficial effect of antibiotics has generally varied inversely with the enteric disease conditions prevailing in a given herd. In one early experiment the use of a tetracycline antibiotic tripled the daily rate of gain and reduced the feed requirement per lb. of gain from 20 to 3.5 lb. In other later experiments the same antibiotic has had no effect on daily gain or feed efficiency.

Antibiotics have had their greatest value in the diets of young pigs, prior to weaning and up to a weight of approximately 100 lb. The use of antibiotics in rations for sows has been favorable in some cases and without effect in others. In most cases the positive effects have not been large enough to warrant the cost of the drug.

Levels of the various drugs used have varied and recommendations of various Stations have varied. However, levels of 10 or 15 gm. per ton of total feed, have been commonly employed for weaned pigs. For starters or creep feeds levels have generally been in the range of 20 to 50 gm. per ton of feed. Much higher levels have been useful in therapeutic formulas.

The mode of action of antibiotics has been studied extensively, but the question has not yet been resolved. On the basis of published data it appears that the favorable effects of antibiotics are due to selective action by the drugs upon the microorganisms of the digestive tract.

Chlortetracycline (Aureomycin), oxytetracycline (Terramycin), procaine penicillin and bacitracin have been the most frequently used antibiotics. Streptomycin has also been used to some extent. Combinations of penicillin and streptomycin and penicillin and bacitracin have also been sold for feed use for several years. Neomycin, subtilin, rimocidin, polymixin and chloramphenicol have been fed to pigs without benefit (127). The tetracycline antibiotics have been more effective in swine rations, on the average, during the first half of the present decade than penicillin or bacitracin.

From the start concern has been expressed that the continuous use of specific antibiotics in feeds would eventually result in an increase of drug

resistant strains of pathogenic microorganisms. This concern is understandable in view of the fact that drug resistant organisms have developed in human medicine. To date, however, no proof that this has occurred has appeared in the literature on swine.

Present research in this field includes studies of new antibiotics, antibiotic combinations, antibiotic and arsonic acid combinations and antibiotic and sulfonamide combinations.

Arsonic Acids. Interest in arsonic acids as feed additives for the improvement of growth in animals had its inception with the report of Morehouse and Mayfield (130) in 1946. These workers reported a marked growth stimulation in chickens and turkeys fed 3-nitro-4-hydroxyphenyl arsonic acid in the drinking water. Subsequent studies by Morehouse (131) and by Bird *et al.* (132) showed that similar effects could be obtained by the direct addition of the drug to the feed.

Carpenter (133) reported growth studies with this arsenical for pigs in 1951, and later reported on the efficacy of two arsenicals in controlling swine dysentery (134). Frost *et al.* (135) reviewed various studies with arsanilic acid and related compounds in 1955. Frost and Spruth (136) reviewed the use of arsenicals in feeds a year later. Both of these papers have extensive bibliographies.

Studies with swine indicate that arsonic acids exert their principal action in a manner similar to the antibiotics—through their effects on the microflora. On the average, the arsenicals have not been as consistent as the tetracycline antibiotics in increasing live weight gains. However, Carpenter and Larson (134) demonstrated that 4-nitro and 3-nitro-4-hydroxyphenyl arsonic acid are much more effective against swine dysentery than the antibiotics.

Since these compounds contain arsenic they are toxic when improperly used. Their toxicity varies markedly and appears to be related to the amount of arsenic deposited in tissue (135). Minnesota studies (137) and those of others have shown that pigs fed an arsonic acid retain arsenic in the tissues, primarily in the liver and kidneys. Retention in muscle tissue has never exceeded 0.5 ppm in Minnesota studies. However, most of the retained arsenic is promptly excreted when the drug is withdrawn from the feed. Hence it is recommended that the drug be withdrawn 5 days before slaughter. No toxicity to the pigs has been observed in any of the Minnesota studies.

The two most commonly used arsenicals in swine feeds are arsanilic acid (p-aminophenyl arsonic acid) and 3-nitro-4-hydroxyphenyl arsonic acid. The manufacturers' recommendations as to levels are 90 gm. for the former and 22.7–34.0 gm. for the latter per ton of total ration. Levels in concentrates are varied according to the protein content of the concentrate.

These compounds have not reecived nearly as much attention as the antibiotics. However, research is now in progress at several stations. These

include not only studies of the individual arsenicals but combinations of these with various antibiotics.

Nitrofurans. Nitrofurans have received only limited study in swine rations to date, though hundreds of experiments have been conducted with them in human medicine. Many studies have also been made with poultry. Extensive bibliographies of studies with animals have been published (138). Two of these compounds, nitrofurazone and furazolidone have been reported to be markedly effective against Salmonella cholerasuis and vibrio dysentery in swine.

Changes in Methods of Feeding

Self-feeding. In 1907 Shaw (139) stated, "Self-feeders have been used in feeding cattle, sheep and swine, but more commonly they are used in feeding sheep". It appears that Evvard (140) was the first to promote the idea of self-feeding. In 1914 he presented a paper on the free-choice system of feeding swine and stated that pigs self-fed, free-choice, from weaning (45 lb.) shelled corn, meat meal, whole oats, linseed oil meal, charcoal, limestone, salt and water weighed 316 lb. at 8 months and 4 days of age. These results were fully as good as those obtained by feeding according to Dietrich's (Illinois) standard. In a later report (141) he suggested that each feed did not have to be fed separately, but that similar feeds could be combined.

In 1926 Henry and Morrison (142) summarized the results of 17 experiments in which hand-feeding and self-feeding were compared (conducted at Missouri, Ohio, Illinois, U.S.D.A. and Kansas Stations). These data showed that self-feeding produced more rapid and more efficient gains. By 1930 the slop barrel was fast disappearing from the commercial hog farms of the Corn Belt. Now, as then, self-feeding is recommended for market animals but not for breeding stock unless the rations are made very bulky. Hand-feeding of market pigs which weigh over 100 lb. is still the recommended practice in many European countries and in Great Britain, because it enables the feeder to produce a leaner market hog.

For the past 30 years probably most hogs in the Corn Belt States have been self-fed by the free-choice method, from weaning to market weight (if they were fed supplements at all). In recent years questions have been raised as to the pig's ability to balance his own ration and it has been suggested that a preferred procedure is to self-feed a complete mixed ration. Most are agreed that the latter is the preferred procedure for creep-fed or early weaned pigs until they weigh 50–75 lb., for pregnant sows which are self-fed, and for all rations not based on corn. However, recent studies reviewed by the author (58) show that free-choice feeding is still a satisfactory method for feeding older market pigs corn and supplement, provided the supplement is designed for that purpose.

The Use of Pasture. Fifty years ago pasture was indispensable for economical swine production. The pasture, if of good quality, supplied many vitamins, some protein and calcium. As rations have improved the nutritional advantages of pasture over dry lot feeding, for market pigs, have diminished. In 1955 (143) the author compared pasture and dry lot data obtained at the Minnesota Station, and raised the question whether the use of land for hog pasture was the best use of that land.

Conrad and Beeson (144) have reported three experiments in which dry lot feeding and pasture feeding of self-fed pigs were compared. The pasture was either alfalfa-ladino clover or ladino clover of excellent quality. The rates of gain were about the same under both systems of feeding. The pasture fed pigs required an average of 4.9% less feed per unit of gain which was equal at prevailing prices to 66 cents per 100 lb. gain or $23.76 per acre of pasture (20 pigs per acre x 180 lb. gain per pig x 66 cents per 100 lb. gain).

The commercial development of low cost vitamin supplements during the past 10 years has made it unnecessary for the feeder to depend on natural feedstuffs as a source of vitamins, if he so wishes. For example, if the feeder wished to feed pigs in a closed building, without sunlight and with no vitamin A, D, riboflavin, niacin, pantothenic acid or vitamin B_{12} supplied in the basal ration he could add these vitamins in ample quantities for 75 to 80 cents per ton of complete feed, at prevailing prices.

There are other cost items, such as labor, which have to be considered as well. However, many producers are now shifting their feeding operations from pasture to dry lot.

Early Weaning. Prior to the development of the new information regarding protein, vitamins and antibiotics orphaned pigs were hand raised successfully only by skilled husbandmen with methods developed by trial and error. Small numbers of pigs were laboratory raised on artificial diets in the early studies of some nutritional problems. Attempts to raise baby pigs on a practical scale, even with milk diets were usually quite unsuccessful.

Following the discovery of the effectiveness of antibiotics feed formulas high in dried milk were developed for liquid feeding of pigs weaned at a few days of age. Excellent results were secured in many cases. In the producers hands these preparations were less successful and less economical and they were not generally accepted. In 1953 Crampton (145) reported the successful rearing of pigs weaned at 10 days of age and fed dry meal mixtures to 56 days. Crane (146) reported the successful rearing of pigs weighing 10 lb. or less on a dry formula containing a large amount of dried skim milk and whey. In 1954 Speer *et al.* (147) reported the successful rearing of pigs weaned at 7 to 14 days of age and fed dry formulas.

The same year the Minnesota Station weaned several hundred pigs at 21 days of age, fed them various dry feed mixtures containing only 12% of dried milk, and obtained excellent 56-day weights. Figures 2 and 3 show

Figure 2. Newly weaned pigs, 3 weeks old. The pigs were offered a choice of three feed formulas containing no sweetening agent, 10% sucrose or saccharin (equivalent to 10% sucrose). (Univ. of Minn. photo).

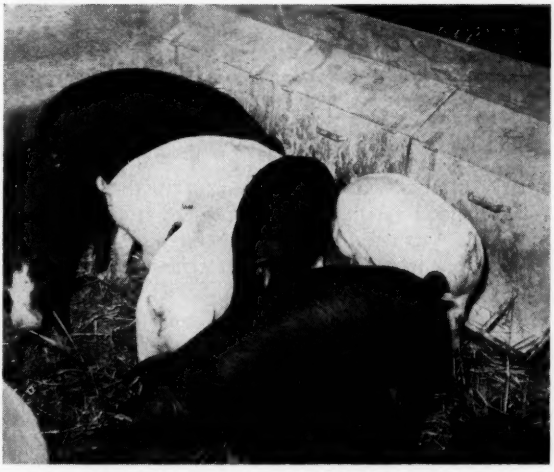

Figure 3. The same pen of pigs shown in Fig. 2, 8 weeks old. Of the total feed consumed 78.2% contained 10% sucrose, 12.8% contained saccharin and 9.0% contained no sweetening agent. (Univ. of Minn. photo).

pigs fed in a preference study. However, in a subsequent study it was found that pigs weaned at 3 weeks of age gained more slowly and required 7% more feed per unit of gain from 8 weeks to market weight, than pigs weaned at 8 weeks. Both groups weighed the same at 8 weeks. Many studies since have not revealed the reasons for this slump in post 8-week performance of the early weaned pigs.

Numerous studies have been made by many others during the past 4 years. While there is a trend toward early weaning today, the practice of weaning at 3 weeks or less is not in general use. A few large producers are weaning at 3 to 5 weeks of age.

Figure 4. These littermate barrows (from left to right) weighed 45, 43, and 44 lb. on May 28. They weighed 72, 123, and 181 lb. respectively on Aug. 18, date of photo. See text for rations. (Univ. of Minn. photo).

For the past 10 years nutrient requirements of baby pigs have been studied in many laboratories. These have included studies of carbohydrate sources, amino acid, vitamin and mineral requirements, fats, antibacterial agents and the use of enzymes. Many of the recent studies were reviewed by the author in 1957 (58). The information gained in these and in early weaning studies are being applied by the feed industry in the manufacture of feeds for small pigs. The net effect has been a noticeable increase in average weaning weights.

How Much Progress Has Been Made?

In 1953 (148) the Minnesota Station conducted a swine feeding demonstration to show the progress that had been made in fundamental swine nutrition as well as its application. The demonstration was also planned as a tribute to the persons who contributed to that progress, only a few of whom are cited in the preceding reviews.

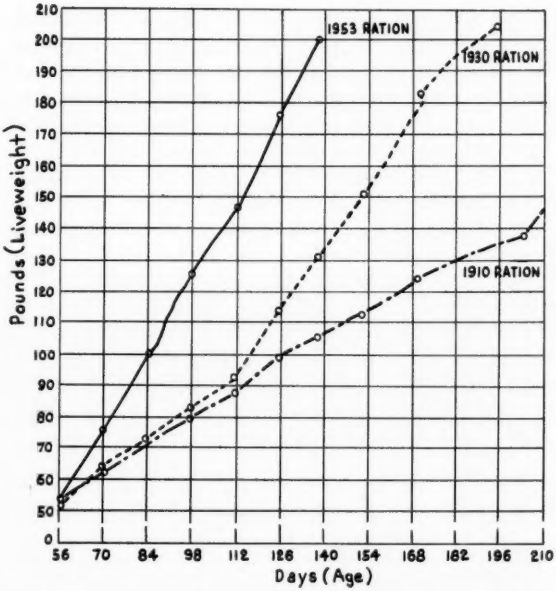

Figure 5. Liveweight gain curves of pigs fed in Test 1. Note similarity of curves for 1910 and 1930 rations until pigs, fed the 1930 ration, reached a weight of 92 lb. The pigs fed the 1910 ration were switched to the 11% protein, 1953 ration between 130–140 lb. average weight.

Eighteen pigs were fed in two series, labelled Test 1 and Test 2. The pigs in Test 1 consisted of one set of 3 littermate barrows of each of three purebred breeds. The pigs within sets were selected within a weight range of 3 lb. They were started on feed immediately following weaning (8 weeks) at an average weight of 51.5 lb. The pigs in Test 2 were crossbreds from three different litters, were 90 days of age and weighed an average of 81.5 lb. at the start.

The rations fed were labelled as 1910, 1930 and 1953. The 1910 ration was intended as a reflection of general feeding practice of that era and not as a reflection of the feeding recommendations of 1910. A further modification was made in that the pigs were restricted to concrete (all swine specialists in 1910 stated that pasture was essential) to simulate what some producers frequently label as pasture. The pigs were given supplementary vitamins A and D, as a substitute for sunshine and the few spears of grass they may have gotten from a very poor pasture. The basal diet was composed of 97% ground corn and 3% of a complex mineral mixture.

The 1930 ration was corn and tankage with some added minerals, plus a vitamin A and D supplement. Corn and tankage was a commonly used ration at that time. The 1953 ration was composed of 80.2% ground corn, 8.2% soybean oil meal, 3.6% tankage, 1.8% linseed oil meal, 5.0% alfalfa meal (dehydrated), 0.7% bone meal and 0.5% trace mineralized salt, plus 10 mg. B_{12} and 10 gm. antibiotic per ton of feed. Supplements of vitamin D and of riboflavin, niacin and pantothenic acid were fed also. The protein level was approximately 14%. When the pigs weighed 125 lb. the protein level was reduced to 11% by increasing the corn and decreasing the proportion of soybean oil meal, tankage and linseed oil meal. The protein levels of the corn and tankage ration were also held at 14% and 11%. All rations were self-fed.

Test 1 was started May 28 and the pigs shown in figure 4 were photographed August 18, when the average weight of the pigs fed the 1953 ration was 200 lb. The liveweight gain curves of all (9) of the pigs are shown in figure 5. The pigs in Test 2 were older and heavier at the start of the test. Their liveweight gain curves are shown in figure 6.

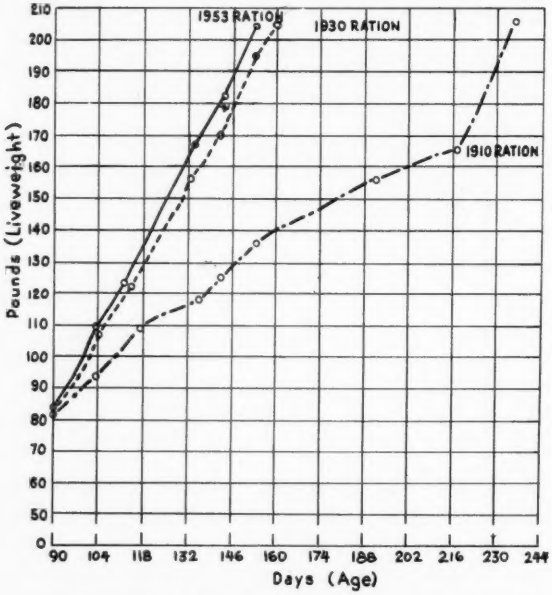

Figure 6. Liveweight gain curves of pigs fed in Test 2. Note the small difference between the 1930 and 1953 rations for these older heavier pigs. The pigs fed the 1910 ration were switched to the 11% protein, 1953 ration at an average weight of 165 lb.

It is apparent that the initial age and weight of the pigs greatly influenced the response to the ration treatments. There was little difference between rates of gain obtained with the 1930 and 1953 rations when the pigs were started at 81.5 lb. (figure 6). On the other hand, the 1930 ration was very little better than the 1910 ration for the lighter younger pigs (figure 5). Note that as these younger pigs reached a weight between 90 and 100 lb. their gain curve turned upward and was more nearly parallel to that of the pigs fed the 1953 ration. The pigs fed the 1910 ration (figure 5) were shifted to the 1953 ration (11% protein) when they

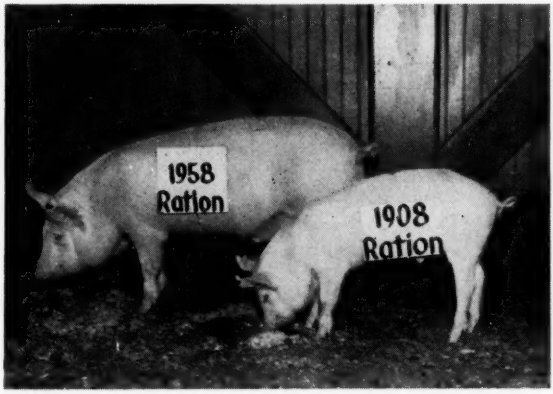

Figure 7. These pigs weighed 33 lb. each at the start. The "1908 pig" gained 7 lb. and the "1958 pig" gained 99 lb. in 62 days. From demonstration by R. J. Meade. (Univ. of Minn. photo).

weighed between 130–140 lb. The following 35 days they gained an average of 69 lb. each. Similarly, the older pigs (figure 6) were shifted to the 1953 ration (11% protein) when they weighed 165 lb. The following 21 days they gained 41 lb. each.

This year Meade (149) conducted in part, a similar demonstration (figure 7). However, he started with 33 lb. pigs. These smaller pigs gained only 0.1 lb. per day and required over 12 lb. feed per lb. gain, when fed a ration of corn, minerals and vitamins A and D. The pigs fed a modern high energy ration based on corn, soybean oil meal, tankage, fish meal and mineral, and supplemented with vitamins and antibiotics gained 1.6 lb. per head daily and required only 2.8 lb. feed per lb. of gain. The pigs were fed for 62 days, not to 200 lb.

These 1953 and 1958 data confirm the fact, known in general for more than 50 years, that the nutrition of the young pig is more critical than that of the larger older pig. The data show also that the cumulative effect

of 50 years of research in swine nutrition has resulted in marked improvement in rations for young pigs.

In 1910 Henry (3) summarized data from over 500 feeding experiments with more than 2200 pigs, conducted at many U. S. Experiment Stations (Feeds and Feeding, p. 502). The following tabulation is adapted from his summary and the 1953 Minnesota demonstration.

The reader may make his own interpretation. It should be kept in mind, however, that the differences shown reflect not only the changes in nutrition, but changes in breeding and management as well. It is clear, however, as

CHANGES IN RATE OF GAIN AND FEED EFFICIENCY, 1910 TO 1953

Source	Weight range of pigs	Average daily gain	Feed per lb. gain
	lb.	lb.	lb.
Henry, 1910	50–100	0.8	4.00
Minnesota, 1953	51–125	1.7	2.97
Henry, 1910	100–200	1.15	4.60
Minnesota, 1953	125–200	1.92	3.87
	From 50 to 200 lb.		
Henry, 1910	50–200	1.00	4.40
Minnesota, 1953	50–200	1.81	3.44

stated by Almquist (150) that, "The past 25 years or so have seen a dramatic change in the principles and practices of nutrition. This may be described as a transition from an ingredient basis of feeding to one of a nutrient basis. In other words, what took place was the abandonment of empirical feed formulas in favor of the consideration of specific requirements of amino acids, vitamins, minerals, etc.".

The Future

Continued progress can be expected from well-planned research. This progress will come from a better understanding of specific nutrient requirements and the interrelations betewen them, for swine of all ages. Much of our present knowledge regarding quantitative nutrient requirements pertains only to the growing pig. Likewise, the interactions between nutrition and breeding and between nutrition and other environmental factors will be determined more precisely. This will enable us to develop more nutritious and suitable diets for specific purposes and specific conditions.

"The immense improvements of recent years in agricultural practice are largely founded on the purely scientific investigation of the preceding generation. The progress of the future must be founded on the scientific research of the present." This statement (from a letter of a "well-known investigator") was included in an address by President H. P. Armsby at the Annual Meeting of the American Society of Animal Nutrition in 1909 (151). It is equally appropriate today.

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FIFTY YEARS OF LIVESTOCK JUDGING

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I HAVE asked for and received permission to discuss the contributions made by livestock shows, and the judging done at these shows, in the improvement and change in livestock type and conformation during the past 50 years.

A. E. Darlow

In order that we may have some basis on which to consider the changes that have taken place during the past half century, I think it is well that we take a very brief look at the early development of our purebred breeds of meat animals and horses.

Development of Breeds. Let's look at the early history of the beef breeds, some of the mutton sheep and several of the hog breeds as they developed in Great Britain. We find that exhibits, shows and competitions played a real and vital part in the development of each of these breeds. During those formative years the breeding of livestock was largely an art; however, the master breeders paid more attention to utility, efficiency of production, and placed more emphasis on the qualities that produced meat which would suit the consumer, than did the average livestock producer of that time.

Although it was largely an art, the judging and determination of type was not based on beauty alone, but on utility as well. I think we need, likewise, to realize that the conformation and type of the animals that we work with today are the result of gradual changes that have come about, perhaps as a result of concensus of opinion among the producers, processors and consumers of what a utility beast should be. So as we discuss the evolution of livestock shows in the United States during the past 50 years, I think we need to remember that the master breeders who gave us these breeds of livestock made a great deal of improvement and passed on to us a much more superior beast than the one they received. Examples of this improvement are shown in figures 1 and 2.

The Place of Livestock Shows

In spite of the influence of livestock judging on the livestock business, there are scientists among the agricultural workers who think that livestock shows are obsolete, and that if they were ever useful, they no longer

are. There are some breeders who likewise think the findings of science are either for scientists or for the birds, but of no use to them. We realize that the large percentage of people engaged in research, production, judging and processing of all livestock are those who recognize the importance of the art as well as the science of livestock production. They are doing their best to make maximum use of both the art and the science.

Type and Productivity. There will be among the readers of this article those who are firmly convinced there is no relationship between type and conformation and productivity. I would be among the first to admit that

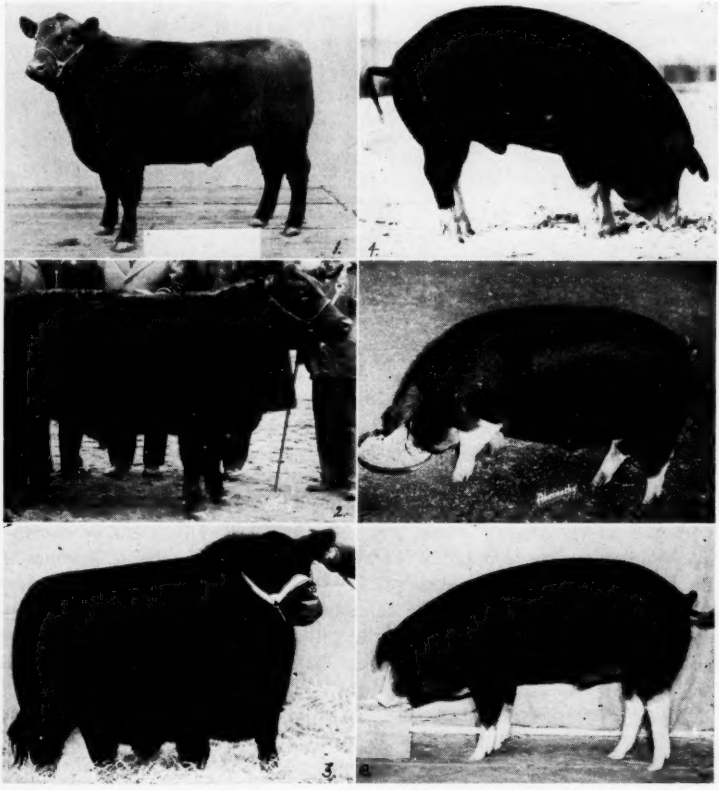

Figure 1. Changes in show ring type of Angus steers and Poland China barrows. 1. A 1600 lb. "slow doing" kind, 1908. 2. Approaching the kind demanded by producer and consumer, 1934. 3. The modern efficient type—over 50 years of evolution, 1954. 4. The "lardless, meatless type" of 1934. 5. A "good doing" fat type—we needed fat for the war effort, 1947. 6. The modern meat type—the most efficient evolved to date, 1957.

this may be true when one is talking about the very minor points within a breed. But when one considers the difference between dairy and beef type, he realizes there is quite an important relationship between conformation and productivity because the beef cow will not produce milk at the same rate the dairy cow will, nor will the average dairy cow produce as much or as high a quality meat as the beef cow. So sketching the subject with broad strokes, I think we may state that up to a point, there is a relationship between conformation and productivity, whether it be beef cows, horses, sheep or any other domestic animal. The relationships between

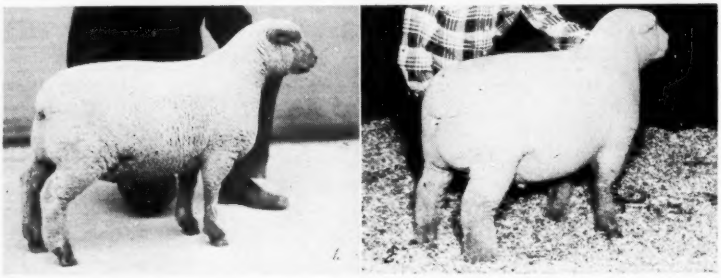

Figure 2. Show ring type fat lambs. 1. A good kind even today, 1937. 2. A "better doing", thicker kind developed in 20 years, 1953.

type and production are cited by Cole *et al.* (Proc. Western Section, Am. Soc. Animal Prod. 9: VII, 1958).

The breeders and judges have taken advantage of the major differences and have built on them. I should like to remind everyone that any of us who is in the livestock production business exercises judgment of a kind. By that I mean we judge our animals daily, just as the livestock judge judges purebred animals in the show ring.

As we are thinking of shows, and the improvement that has been made in them, we realize that today we have not only the breeding animals in the arena, but carloads of feeder cattle, carloads of fat cattle, carcass contests (both on foot and as the carcasses hang in the coolers), we have contests to determine the best animal, the one that produces most economically. When we consider all these factors, then we can see that livestock shows still have an opportunity to make a contribution.

Role of Livestock Judges. A judge of purebred livestock is not a dictator. He is not a man with a preconceived, definite notion of just what type should be, and a determination to impose it on all breeders. The opinion a judge carries with him into the ring is a composite of his own experience through the years, the ideas of breeders, processors, consumers and scientists. The kind of a beast he puts at the head of the class, or the winning beast in a steer show, is usually the best compromise of all of these elements. It is the judge's job to interpret the consumers' desires into the kind

of a beast that will, for the most part, meet the requirements of all of these, keeping in mind at the same time that this should be the kind of beast the producer can afford to produce.

Referring now specifically to beef cattle, I have said on occasion that the beef animal is the kind of beast that will convert roughage, whether it is grass or harvested forage, into meat, and the kind of beast that can walk out and get grass or the forage if necessary. The average consumer, if he could afford it, would prefer rib, loin, rump and round only. In order to have a beast that can convert rough feed into meat, it is necessary that we have a great depth of body. It is the judge's business, as I say, to get the best compromise between what is wanted by the consumer and what a breeder can afford to produce. In my opinion, this has resulted in the type of meat animal we have today.

Livestock Shows and Changes in Type. The successful livestock breeder, the producer of purebred livestock today, is a man who is likewise making use of the art and science of livestock breeding, and the art and science of livestock nutrition and management. The knowledge of and the use of laws of inheritance have made it possible to make more rapid improvement in livestock type in the past several years than was possible 40 to 50 years ago. It has made it possible to more quickly adjust type of certain of the species to present day demand. There has been perhaps more progress in the breeding of swine than in cattle or sheep. This is the result of the combination of efforts of the swine producer, who knew the art of breeding pigs, and the scientist and geneticist who helped him practice the art with a great deal more precision.

Those changes in the type of pig could have been made without livestock shows. They could have been made without shows of market hogs and gatherings of farmers to see the latest developments. However, *livestock shows are the means whereby type changes are called to the attention of the public*. Here the thinking of the producer and breeder is crystallized. There is no real substitute for this exchange of ideas and the opportunity to see the results on foot. Means are developed whereby the judges of the livestock can interpret to the average breeder the type and conformations that will do the job he wants done. I say this could be accomplished without the livestock shows, but we would have only a few of the desirable animals rather than many, because it is necessary that this information be made available, and in such a way it can be useful to the average producer. The livestock shows do this, and the judge has a real part in it. So behind the beast, the show and the judge, is a mighty battery of men, not only in the United States but world wide, each making his particular important contribution to the field of livestock production. These men may be classified as the scientist, the producer, the market man, the educator and the consumer.

Livestock Improvement. Fifty years ago the scientist in livestock breeding was pretty well going it alone, for it was just 50 years ago that the

first organization of national scope brought together men with a common problem—the scientist and the practical producer—in an organization designed to work improvement in livestock production.

Today these men, organized but still working as individuals, make scientific contributions that cannot be detailed here, but one realizes how tremendous is the information that has been gathered in the past 50 years on animal nutrition, such as the need for certain vitamins, trace minerals and proper amino acid combinations. One realizes that all or much of this information is now being used in the feeding of animals. He realizes that the scientist has made a contribution that the judge uses as he places animals in the ring. The contributions made by the animal geneticist, livestock breeder, physiologist, pathologist, and parasitologist all have had an impact on the kind and quality of animal that we produce today, and particularly on the efficiency with which he is produced.

I always think, as I see animals walk into the ring, that that particular animal one sees is the result of the art and science of breeding and nutrition. There he is, the grand steer, at one of the leading shows, the essence of the combination of all the sciences and art. The judges contribution is, as I see it, to interpret to the public the kind of an animal that should be produced. In placing the animals, and giving a brief explanation as to why a particular animal was placed at the top, the judge helps to crystallize the thinking and opinions of the breeders.

For those among us who think there is too much attention paid to some uneconomic details in the purebred livestock shows, let me remind you that the producer of purebreds can be likened to the maker of machine tools. We have an outstanding industry of livestock and meat production in the United States, not because we have a great many people breeding purebreds, but because practically all of the good producers are calling on the purebred man for their seed stock or "machine tools" in order that they can make progress in the primary essential industry of our nation—the feeding of people. For success cooperative effort of the livestock producer, the marketing agent and the consumer is essential.

The Producer. In the show ring the purebred breeder is exhibiting the end result of the contributions made by the scientist and himself working together, not ever in total form or in perfection, but in the knowledgeable use of means and methods of study. The final signal of the judge is a conscientious effort to put together the knowledge of the scientist in the production of the animal.

The Market Man. Farther removed from the field of science, and the personal satisfaction of the scientist and the breeder is the man who markets the animal. His interest must of necessity lie in the field of economics to a greater extent than either the scientist or the producer. He must take what he gets and get what he can. He is the man who "uses" the scientist and producer for utilitarian purposes.

The Consumer. The consumer is even further removed from the field of science and production, but his needs and wants will determine the freedom with which the scientist, the producer and the market man will operate.

The happiest of situations in judging is the man who is a scientist, a producer and a market man. He is always a consumer. But even given this happy and unusual circumstance, the judge will not be objective, for he must make a personal judgment of worth. He can never make a perfect judgment, but he can make, to the best of his ability, a compromise. He can see and understand and appreciate the contributions of science, the limitations of the producer, the pressure of the market man. He can look at the product before him. How the beast standing before him measures up to the demands of the men arrayed behind him is the telling point.

The past 50 years have seen the youth agricultural groups of the country drawn together with many objectives. One of the primary objectives is the improvement of livestock. Here the value of the judge, and the show cannot be overlooked. Both are tools of education, of the development of interest, of putting into practice the knowledge in the field. The fact that many of these young men and women, coming into contact with educators in the field, turn their interest to education in agriculture, or in one of its many related fields, proves that livestock shows are making a worthwhile contribution.

The past 50 years has seen a tremendous increase in the size of the show but its primary function, and its real value remains the same, that is to bring people together for a time of discussion of common problems. The show helps build greater demand for the product, a better understanding of one another's problems, an extension and dissemination of knowledge, and the promotion of prosperity for everyone in the field of animal husbandry. It offers a focal point for the proof that investigations and research are being put into production.

Stock shows during the past 50 years have proven to be the outstanding classrooms, or laboratories, for the assimilation, coordination, and dissemination of information in the art and science of animal husbandry. Some of our outstanding judges have, in my opinion, proved to be master teachers and have had an influence beyond our ability to evaluate—not only on the type of animal that is now being produced but upon the general business of livestock production. Men such as Deans H. H. Kilde, W. L. Blizzard, and A. D. Weber (with his over ten years of continuous judging of steers at the International) have had a tremendous influence on the type of beef cattle produced today. R. G. Grummer and J. C. Hillier have had a like influence on type of swine and J. C. Holbert and H. M. Briggs have made lasting contributions on sheep type. Each of these men who has walked into the classroom of the arena, for all the world to see, has proved to be a master teacher.

FIFTY YEARS OF PROGRESS IN ANIMAL PHYSIOLOGY

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THE achievements of research workers in the Land Grant Colleges and Agricultural Experiment Stations, and in various organizations for agricultural research throughout the world have been far greater than their founders expected or dreamed possible. It was anticipated that the researches would be practical and capable of direct application by producers of crops and animals. While our original objectives may have been toward applied research, the nature of the problems we have studied have demanded the most fundamental approaches. When we summarize the accomplishments it is gratifying to discover that while we have doubled or tripled the growth rates of animals, we have gained insight into the most intimate details of the cellular and intercellular phenomena of growth; that while we have increased the prolificacy of farm animals, we have also led in the solution of problems in gametogenesis, fertilization and embryology; that while we have modified the animal and the environment to suit each other, we have solved the riddle of the role of light in endocrine function and have learned of the relationship of cosmic radiation in gene change; and that in the process of doubling or tripling milk production, we have learned more about the nature of the secretory process than is perhaps known about any other biological product. The entire membership of the American Society of Animal Production can be proud of its participation in this achievement.

F. N. Andrews

It would be presumptious for one person to attempt to review the important contributions of the entire science of physiology. I have therefore limited myself to several areas in which our members have been particularly active. Since the physiology of milk production was reviewed by Reece in The Golden Jubilee issue of Dairy Science in 1956 it was not included here. It would be impossible to cite all of the references, but an attempt has been made to include sufficient review papers that nearly all of the important contributions can be found by consulting the references at the conclusion of the paper.

The Physiology of Growth

The Measurement and Expression of Growth. Problems involving the definition, measurement and expression of growth concern plant and animal

scientists, geneticists, nutritionists, biochemists, physiologists, farmers, processors and consumers. Our present understanding of the nature of growth and effective ways of measuring it cannot be credited to specific scientists since countless thousands of individual contributions have been made. Those of us in the animal sciences owe much to the efforts of Samuel Brody for his classic work "Bioenergetics and Growth" (1). In this book he brought into focus the contributions of such 20th Century biologists and mathematicians as J. S. Huxley, Jacques and Leo Loeb, Alexis Carrel and Raymond Pearl and chemists such as Armsby, Barcroft, Benedict, Bonnet, Borsook, Dubois, Krebs, Lusk, Mitchell, Mollgaard, Rubner, Ritzman and others. These scientists are in a large part responsible for the methods which all of us use in measuring and describing various growth phenomena.

The most common measure of growth is absolute gain in weight per unit of time as represented by the equation:

$$\frac{W_2 - W_1}{t_2 - t_1} = \frac{\text{larger wt. less smaller wt.}}{\text{larger time less smaller time}}$$

For most short term experiments this growth measure is adequate. It usually does not give a satisfactory description of the growth process for the entire life span or for making comparisons of growth between widely different species or breeds within a species. Thus a 1000 lb. animal at an age of 1000 days from conception appears to have gained at a rate of one pound per day. It is obvious that average daily gain under such conditions is highly misleading. Brody suggests that true growth rate might be called instantaneous relative growth rate, $k = \frac{dW/dt}{W}$, where dW represents the exact weight at an interval (dt) so short that the velocity of growth cannot change and W equals the weight at the instant the rate dW/dt is measured. Since this concept is essentially theoretical the integrated equation $W = Ae^{kt}$ in which e is the base of natural logarithms and A is the natural logarithm of W when $t = o$ is applicable when relative growth rate is a function of growth already made. When relative growth rate is a function of growth yet to be made as maturity is reached the equation would be $\frac{dW}{dt} = -k\,(A - W)$. The integrated form of this equation is $W = A - Be^{-kt}$ in which A is the mature weight and B a constant. Brody applied these and other equations in a large number of studies involving body and organ growth and metabolism to species ranging in size from the canary to the elephant. Among his collaborators were Ragsdale, Trowbridge, Kempster, Mumford and Turner plus an outstanding group of graduate students. Data gathered by earlier Missouri workers such as Moulton, Eckles, and Waters were also evaluated, and the Missouri Experiment Station became a leading center for the study of growth.

The Physical and Chemical Nature of Growth. Research workers in agricultural experiment stations throughout the world have been in the forefront in adding to our knowledge of the true nature of prenatal and post-

natal growth. The facts that the nervous and vascular systems develop early in embryonic life, that bone, muscle and fat differentiate in that order, that the skull, brain and skeleton in the forequarter develop earlier than the skeletal structures in the loin and pelvis, and that skeletal development is more rapid than the growth of the muscular system are now common knowledge. Fat deposition might be regarded as a biological luxury. Fatty depots appear around viscera such as the kidney, and with increasing age and adequate caloric intake between the muscles, beneath the skin, and lastly in the form of marbling between muscle fibers. Most of this knowledge has been added in the past half century.

Waters' (2) studies with cattle at the Missouri Station in 1908 were the first in which physical and chemical analyses were applied in an effort to quantitate the growth process. He showed that bone length in the head and limbs of steers increased on maintenance and sub-maintenance rations even when gross body weight remained static or even decreased. Width of chest and width at hips decreased at the expense of long bone growth when nutrients were restricted and fat depots were drawn upon. This work was continued and extended by Trowbridge, Moulton, Haig and Hogan in the period between 1908 and 1929.

In 1932 Hammond, of Cambridge University, introduced the complete body dissection technique which has been used in a number of detailed studies with sheep and swine. The various organs, and tissues such as muscles, skin, bone, blood, nervous, vascular and connective tissue are removed and weighed. A variety of statistical approaches for studying variables such as sex, age, weight, protein, fat and mineral composition immediately present themselves. The work of Hammond, McMeekan, Pomeroy, Verges, Wallace, and Palsson in which the dissection technique was applied to swine and sheep has been reviewed in detail by Palsson (3). These workers described in a most complete way the effects of age and sex on the development of the skeletal, muscular and organ systems of sheep and swine. In addition, they renewed the interest in plane of nutrition and the development of various parts of the body which Waters had first created in 1908. Their studies on high and low planes of nutrition at different stages of the growth period and the marked alteration which was produced in skeletal and muscular structures and fat deposition created wide interest and had a profound effect on experimental procedures used throughout the world.

The Endocrine Regulation of Growth. Professional endocrinologists are undecided as to whether this branch of physiology had its origin with the studies of Berthold on fowl testes in 1849, the demonstration of Brown-Sequard in 1888 that testis extracts were related to sexual rejuvenation, or to those 20th Century scientists who were successful in the isolation and identification of the ovarian and testicular hormones. The fact that castration was performed by primitive man during the time when he first concerned himself with animal domestication is irrefutable evidence that man

has been a practicing endocrinologist for many centuries. He clearly recognized that testicular removal made animals more tractable and less likely to roam, that it prevented the development of sexual odors in the boar, and he probably observed that it increased fat deposition in years when abundant animal feed was available.

The differences in rate and type of growth in male, female and castrate farm animals described by such early workers as Waters and Marshall and later by Tandler and Keller, Brody, Hammond, Gramlich and Hart, and Guilbert and Cole took into account the effects of the sex hormones even though they could not be quantitatively related to them.

F. H. A. Marshall had correctly deduced as early as 1905 that the ovarian follicle was the source of an estrogenic hormone; the first crystalline estrogen (estrone) was produced by Doisy in St. Louis in 1929. The first pure androgens were not available until 1931–34 when Butenandt *et al.* identified the chemical nature of some of the urinary androgens.

The naturally secreted estrogens and androgens were both scarce and expensive during the 1930's. The work of the British biochemist Dobbs with stilbene and its derivatives, begun in 1933, culminated in the synthesis of diethylstilbestrol in 1938 (Dobbs, Goldberg, Lawson and Robinson). Diethylstilbestrol was easy to produce in quantity, relatively inexpensive and produced an extremely high degree of estrogenic activity. The availability of diethylstilbestrol led to an extremely large number of studies as to its effects. Folley, Watson and Bottomley, and Lewis and Turner showed that this estrogen produced extensive mammary gland growth in the goat and laid the foundation for other work on mammary development and secretion. Mark and Biskind showed that diethylstilbestrol was effective when administered in the form of compressed pellets. Thus, for the first time, investigators had an estrogen which was effective when injected in solution, implanted as a solid, or administered orally.

The first practical applications on meat production were made in poultry. These studies were completely reviewed by Lorenz (4) but a few names should be mentioned. Lorenz (1943) was the first to show that subcutaneous implantation of diethylstilbestrol increased fat deposition and improved carcass quality in chickens. Jaap, Thayer and Penquite (1944–45) were the first to demonstrate that the addition of diethylstilbestrol and a series of similar estrogens to the feed would produce fat deposition and improve carcass quality in chickens. In avian species it is now recognized that estrogens specifically increase fat deposition; this is not the case in mammals.

Studies with rats and mice, and other laboratory animals, carried on between 1939 and 1945, showed that natural estrogens and compounds like diethylstilbestrol hastened skeletal aging, closure of the epiphysis and reduced true growth. It was therefore surprising when Andrews, Beeson, Dinusson, Harper and Johnson found that the subcutaneous administration of diethylstilbestrol pellets improved the rate of gain and efficiency of feed

utilization in fattening lambs, heifers and beef steers. These findings were quickly confirmed by Jordan, Pope, O'Mary, Batterman, Bray, Casida and Wilson, and Clegg and Cole (5, 6). Because estrogens had been shown to inhibit growth in rodents, a series of investigations with farm animals has been carried out to attempt to characterize the effects and possible mode of action of estrogens in cattle, sheep and swine. These results are presented in detail in a review of the National Academy of Sciences-National Research Council being prepared by Casida, Andrews, Bogart, Clegg and Nalbandov (1958). The most significant findings involve the nature of the growth response. The work of Clegg and Cole and Whitehair, Gallup and Bell indicated that nitrogen retention occurs in cattle and sheep when estrogen is administered and that true growth is produced. In the first work with cattle and sheep there was a distinct reduction in carcass grade following the implantation of diethylstilbestrol. Subsequent research indicated that estrogens tend to reduce body fat in sheep (O'Mary *et al.*, Whitehair *et al.*, Jordan 1953, and others). As summarized by Clegg and Carroll (7) the reduction of carcass grade produced by diethylstilbestrol is in general proportional to the amount of estrogen administered. As a result, implantation dosage levels of 15, 24 and 36 mg. per beef animal, and 3 and 6 mg. per sheep are now used rather than levels of 60–120 mg. in cattle and 12–24 mg. in sheep as in the early studies. In 1956 Deans *et al.* (8) reported that pellets made up of two natural steriodal hormones, estradiol and progesterone, increased rate of gain and feed efficiency in steers and this preparation is now used in practical cattle production. Following the reports of Burroughs, Culbertson, Kastelic, Cheng and Hale (1954) (9) that the oral administration of diethylstilbestrol effectively increased rate of gain in cattle, the use of hormones, or hormone-like substances, has become widespread. The results will be presented in some of the reviews including the nutrition of various farm animals and are reviewed in the National Research Council report of Casida *et al.* (1958).

The male sex hormones, androgens, are considered to be of more importance in nitrogen retention than the estrogens. As yet, however, they have not proved as adaptable to animal production as the estrogens. This is due in part to the fact that they are more expensive than the estrogens and have been used less in large animal experimentation, that androgen pellets are not as satisfactory as several of the estrogens, and that androgens with high oral activity are not yet available. Experiments involving androgens will be included in the review by Casida *et al.*, but it is appropriate to record a few of the studies here. In Purdue studies with sheep and cattle previously referred to (1949–1954) testosterone propionate was injected in oil solution at widely separated intervals, and compressed pellets were implanted. In some instances growth rate appeared to be increased and in some cases there appeared to be an improvement in carcass quality. Burris, Bogart and Oliver (10) injected steers and heifers with testosterone at weekly intervals; both showed an increase in rate of gain but the response was most marked in heifers.

Early studies of the effects of estrogens on swine were not impressive (reviewed by Sykes *et al.* (5)). Work by Dinusson, Klosterman and Buchanan, Braude and Murphree *et al.* suggest that there is no significant effect on growth or feed efficiency but that the genital and mammary tissues show marked stimulation. The implantation (Woehling, Wilson, Grummer, Bray and Casida, Bratzler, Soule, Reineke and Paul), injection (Sleeth, Pearson, Wallace, Kropf and Koger), or feeding (Beeson, Andrews, Perry and Stob), of androgens has thus far not been too encouraging. When Beeson *et al.* fed methyl testosterone in the ration there was a suggestion of some increase in the lean or muscular cuts. This is being explored in several experiment stations but is far from practical exploitation.

The role of the thyroid gland in growth and development has been studied by many of the members of the Society. The most significant of these researches were summarized by Sykes *et al.* (5) but some of the names should be recorded here. The growth depressing effects of thyroidectomy have been demonstrated by Reineke, McMillan, Bratzler, Turner, Brody and Frankenbach, who have also shown that the administration of thyroxine or thyroprotein will overcome the effects of thyroidectomy. The demonstration by Andrews and Bullard (1940) that hypothyroidism of beef steers produced by partial thyroidectomy resulted in increased fattening, and the production of experimental hypothyroidism with goitrogens contributed to our knowledge of the metabolic processes (Muhrer, Hogan, Beeson, Barrick, Andrews, Perry, Witz, Terrell, Krider, Carroll, Hamilton, Vander Noot, Reece, Skelly, Willman, Asdell and Loosli).

The development of methods for the production of thyroidally active iodinated casein (thyroprotein) by Reineke and Turner (1942) made possible the experimental production of nearly any degree of hyperthyroidism. The effects of hyperthyroidism on growth and milk production have been widely studied (see review by Sykes *et al.*, 5). The addition of thyroprotein to the rations of growing swine frequently increased rate of gain (Reineke, McMillan, Beeson, Andrews, Perry, Witz). However, it was shown that many factors such as dosage level, season of the year, breed, age and weight, nature and amount of feed and others influenced the response and it was nearly impossible to define the conditions under which a favorable response could be obtained.

The principle endocrine regulation of growth is by the secretions of the anterior pituitary gland. Evans and Long of the University of California were the first to produce an increase in growth rate with an extract of the anterior pituitary (1921) but not until 1944–45 did Li and Evans succeed in isolating a protein which behaved as a single substance electrophoretically and which was capable of promoting growth. Improvements in the isolation technique by Wilhelmi, Fishman and Russell (1948) finally made it possible to prepare sufficient material for large animal testing. Baird, Nalbandov and Norton (11), by assaying the anterior pituitary glands of swine of slow and rapid growing lines, showed rather conclusively that

differences in growth rate of these swine were due principally to differences in growth hormone secretion.

Giles attempted without success to alter the growth of swine by the injection of a crude pituitary preparation; this result was not surprising in view of the nature of the preparation used. Turman and Andrews (12), with the advantage of more highly purified material (Armour growth hormone prepared by the method of Wilhelmi *et al.*) produced a highly significant increase in total carcass protein and a reduction in carcass fat in swine treated between 100 and 230 lb. The treated swine gained slightly more per day (2.26 lb.) than the controls (2.19 lb.) and required only 310 lb. of feed per 100 lb. of gain in comparison with 384 lb. for the controls. However, the fact that total carcass protein was increased from 10.8% in the controls to 13.5% in the growth-hormone-injected animals lent added evidence to that presented by Baird, Nalbandov and Norton that effective selection for rapid muscular growth may involve selection for a high level of growth hormone secretion. Studies in man, the dog and the cat have shown that the growth hormone affects carbohydrate metabolism as well as nitrogen deposition and at least some purified growth hormone preparations have been shown to be diabetogenic. Of 11 swine injected with growth hormone seven showed no unfavorable response. Four animals responded quickly and unfavorably, exhibited convulsive seizures over a period of several days, and at death exhibited serious histopathologic changes of the liver and kidney (13).

The Hormonal Activity of Animal Feedstuffs. The first half of the 20th Century has revealed an amazing amount of information on the chemical nature of a great variety of animal feedstuffs. During this period we have gained much knowledge of the specific carbohydrates, amino and fatty acids, mineral and vitamin constituents of all types of grains and forages. We have known since the report of the German scientists Loewe and Spohr (1926) that certain plants contained detectable estrogenic activity, but we did not appreciate until the studies of Bennetts, Underwood and Shier (1946) that plant hormone activity would affect the productivity of farm animals. These workers observed that sheep grazing subterranean clover pastures in Western Australia sometimes showed extreme mammary and genital development and did not reproduce. It was then shown that the estrogenic activity was due to the isoflavone genistein. Cheng, Story, Yoder, Hale and Burroughs (1953) subsequently isolated the same compound, genistein, from soybean oil meal. Pieterse and Andrews (14, 15) have reviewed the work of these and other workers and have studied the estrogenic activity of alfalfa and other feedstuffs under a variety of conditions of growth and maturity, when fresh, dried, or as silage. In addition, Stob, Davis and Andrews found distinct differences in the estrogenic activity of more than 50 strains of alfalfa. While much remains to be learned about the nature and significance of the hormonal activity of feedstuffs, one cannot but wonder if the speculation of Bartlett, Folley and Rowland (1948)

that estrogens in forage may affect milk secretion should not be extended to the processes of growth and reproduction as well.

The Physiology of Reproduction

While there may not be agreement as to what constitutes the most fundamental single property of protoplasm, there can be little disagreement that life would not continue long in the absence of reproduction. Those of us currently engaged in research in reproductive physiology often conclude that all of importance which is known has been discovered in the 20th Century. In order to put our current knowledge in proper perspective it would be well to review the work of those who have gone before. The discovery and description of mammalian spermatozoa by Leewenhoek, Ham and Hartsoeker in 1677–78, the recognition of the Graafian follicle of the ovary by de Graaf in 1678, and the discovery of the human ovum by Von Baer in 1827 established the nature of the cellular units required for fertilization. But, just as nomadic husbandmen were the first practicing endocrinologists, so was an Arabian horseman the first to receive credit for accomplishing the technique of artificial insemination. Several authors report that an Arab chieftain inseminated one of his best mares in 1322; since he stole the semen from a rival chief it is presumed that he must likewise have been the first to transport semen.

In the English speaking world we owe much to the British physiologists Heape and Marshall. These men recognized the great majority of the basic reproductive problems which confront every livestock producer and physiologist, and in the writer's humble opinion we have not yet solved most of them. References to many of the contributions of Heape and Marshall are made by McKenzie and Terrill (16) and Willett (17). Heape was a pioneer in the transfer of ova from one female to another, originated the terms for the stages of the estrual cycle including the period of sexual receptivity (oestrum) and the period of seasonal sexual rest in sheep (anoestrum). He discovered that ovulation depends on mating in the rabbit. His observations that improved feeding prior to the breeding season in sheep (1899) plus the work of Marshall from 1903–1908 laid the foundation for the practice of flushing which many sheep producers have since followed. The publication of Marshall's book *The Physiology of Reproduction* (18) in 1910 had a profound stimulating effect throughout the world.

The Estrual Cycle. Marshall's own research on the estrual cycle of sheep, his observation that sheep ovulate spontaneously, that the ovulation rate is higher early in the breeding season than at the end and that twinning was an individual characteristic created great interest.

The study of the estrual cycle has been a favorite topic for many members of the American Society of Animal Production. In 1909 F. B. Mumford initiated a project at the Missouri Station which has continued for

nearly 50 years. From 1909 until 1920 the principle objective was to determine the effect of early pregnancy on the growth and performance of "well fed" swine; in 1920 a study of the effects of different planes of nutrition on fertility and growth was begun. McKenzie took over the responsibility for this work in 1925, and under his direction were carried out a series of studies involving various aspects of the estrual cycle. Phillips, Allen, Casida, Terrill, Warbritton, Nahm and Andrews studied problems relating to ovulation, endocrine regulation, histology and cytology of the sheep and mare.

Cole and Miller, Darlow and Hankins, Clark, Winters and Green also made important contributions in work on the estrual cycle of the sheep in the United States as did Grant and Nichols in Britain and Quinlan, Mare and Roux in South Africa at approximately the same time interval (1930–40).

Hammond's publication of the book *The Physiology of Reproduction in the Cow* (19) in 1927 provided a valuable source of information on the bovine and was followed, in the 1930's, by many studies, especially on dairy cattle.

The mare was an unusually valuable research animal and knowledge gained in the horse had wide application with other species. The Graafian follicles are very large and can be readily palpated per rectum. Thus time of mating can be easily correlated with actual ovulation. This was recognized by Aitken, Kupfer, Satoh and Hoshi, McKenzie and Andrews and a number of Russian workers such as Kedrov, Mirskaya, Zivotkov and others.

The discovery of the presence of large quantities of estrogens in the blood serum and urine of pregnant mares by Cole and Hart (1930) and the gonad stimulating hormone in the pregnant mare's serum by Cole and Saunders in 1934 was of considerable importance to both man and animals. For many years the urine of pregnant mares was the principle source of the estrogenic hormones, and we still rely heavily on pregnant mare's serum gonadotropin. Cole and Miller carried out a series of studies on the induction of estrus and ovulation in sheep with both estrin and gonadotropin and laid the foundation for the many subsequent attempts to produce lambs during the non-breeding season by endocrine stimulation.

Embryonic Death. In 1914 Hammond observed a marked discrepancy between the number of corpora lutea in the ovaries and the actual number of viable fetuses in swine, and correctly concluded that a substantial number of fertilized ova did not develop normally. Corner's work (1921) showed that a count of corpora lutea was a reliable index of actual numbers of ova produced and it was established that embryonic and fetal mortality was, and still is, a major problem in fertility and prolificacy. Hammond, Corner, Crew and Warwick in independent studies showed that 20 to 40% of the ova produced underwent embryonic or fetal death. Phillips and Zeller (1941) concluded on the basis of their own data and the contributions of earlier workers, that when all losses of swine ova were taken into

account only 27.1% of the ova which had a chance to be fertilized were represented by live pigs at weaning. It had now become apparent that while swine are the most prolific farm animal they are clearly not the most fertile, and research to solve the several problems was undertaken at a number of universities. Wilson, Nalbandov and Krider and Warnick, Wiggins, Grummer and Casida made a systematic study of the anatomical and endocrine abnormalities associated with impaired fertility. In a series of investigations at Wisconsin it was shown that age at time of breeding and various sequences of full and limited feeding affected ovulation rate and embryonic survival. Breeding at the first heat period at puberty resulted in smaller litters than at the second or third heat periods, and in general a high plane of nutrition and increased fattening increased ovulation rate but reduced embryonic survival (Casida, Chapman, Grummer, Self, Robertson). At Missouri a series of excellent studies has shown uterine environment, especially uterine space per embryo, to be of major importance. As found by others their work suggests that age at breeding and backfat thickness are associated with both ovulation rate and embryonic survival (Lasley, Mayer, Squires, Dickerson, Rathnasabapathy and Lerner) (20, 21).

The relationship of genetic makeup and prolificacy of swine will be discussed elsewhere. It should be mentioned, however, that studies of Hetzer, Lambert and Zeller showed that less than 20% of the variance in litter size is heritable, and that increasing inbreeding does reduce litter size and viability. Stewart showed that size of first litter increased in a curvilinear fashion to about 15 months of age. E. L. Lasley concluded that the heritability of litter size was 0, 8 and 5% for the first, second and third litters respectively, and that the heritability of ovulation rate (corpora lutea count) was 10%.

It is apparent that the efficiency of the reproductive process in swine can and must be improved and that the problem is of sufficient magnitude to warrant strong support.

Much less information is available about the incidence of embryonic mortality in sheep. Hammond and Henning estimated the embryonic loss to be 13 to 16%. More recent work suggests that the losses in terms of number of ova produced and lambs born may be as high as 40–60% (Brambell, Dutt, Robinson and Watson, 1954).

In cattle, as in swine, early embryonic death is an important unsolved problem. As reviewed by Robinson (20) American and British workers have made outstanding contributions (Laing and Hamilton, Casida, Tanabe, Kidder and Barrett and others).

Diagnosis of Infertility in the Male. At the beginning of the 20th Century the male was not regarded to be an important source of variability in reproductive efficiency. It was generally assumed that a male was either sterile or fertile and the few observations which had been made were directed to the detection of the sterile male. When the possibilities of

artificial insemination became apparent, the amount of research devoted to spermatogenesis, and the physiology of semen and spermatozoa was increased many fold. There is probably no other cell of which so much is known as the spermatozoon. Research workers in this area of animal science have made invaluable contributions to all branches of biology and medicine. It would be impossible to even mention all of those who have contributed, let alone properly interpret their contributions. The writer believes that the following literature sources will include most if not all of the workers mentioned, and several hundred others as well. McKenzie and Berliner (22) gave a particularly complete review of the work of early Russian physiologists and Weisman (23) included more than 750 citations in his book *Spermatozoa and Sterility*. Mann (24) has made an exceptionally complete review in his book *The Biochemistry of Semen*.

The work of L. L. Lewis (1911) at the Oklahoma Station on the vitality of the germ cells is unknown to many and should probably be given credit as the first of its type in North America. In 1920, Williams at Cornell reported on methods of semen examination in bulls, and refinements made by Williams and Savage in 1927 were widely copied. Donham, Simms and Shaw, McKenzie, Phillips and Berliner, Lagerlof and Gunn did much to stimulate research on semen examination in the United States, Europe, and Australia, and in Russia Iwanov, Kirillow, Milowanow and Zawadowsky carried out work on semen physiology. The first detailed studies on the semen of the ram and boar were performed by McKenzie, Berliner, Miller and Baugess.

Artificial Insemination. In the mid 1930's, the success of the Russian program of artificial insemination initiated by Ivanoff in 1899, and the Danish program organized by Sorenson and Gylling-Holm in 1936 had created great interest in the United States and in Britain. The American Society of Animal Production organized special sessions at its annual meetings to discuss problems related to artificial insemination and must be credited with encouraging research throughout North America. McKenzie, Casida, Cole, Asdell, Winters, Phillips and their graduate students were particularly active in the direction of these meetings and a great share of the workers mentioned in this article participated.

Following the establishment of the first cooperative artificial breeding association in the United States by E. J. Perry in New Jersey in 1938, it became apparent that one of the most pressing needs was the development of better methods of semen preservation. The introduction of the egg yolk-phosphate diluter by Phillips and Lardy in 1940, and the yolk-citrate diluter by Salisbury, Fuller and Willett in 1941 were key factors in the early practical success of artificial breeding. Workers in the Cornell group (Salisbury, Beck, Elliott, Willett, Bratton, Foote and Fuller) greatly extended the practical dilution rate of bull semen, and improved semen preservation through the use of sulfa drugs and antibiotics. The Pennsylvania research in semen physiology led by Almquist, Flipse, Thacker and

O'Dell includes pioneer work in the use of antibiotics, the development of milk dilutors and the use of isotopes in problems of metabolism. The studies of Erb and Ehlers, Mixner and students, and Mayer, Lasley and students have added to our knowledge of semen evaluation, preservation and metabolism. Attention is called to a review of a half century of progress in *Reproduction of Dairy Cattle and in Artificial Insemination* by E. L. Willett (17).

The preservation of a number of pathogenic bacteria and viruses in the frozen state has been routinely practiced for at least a quarter of a century. As reviewed by Mann (24), sperm were subjected to freezing temperatures as early as 1840, but not until 1938 (Jahnel) did it appear that sperm might be capable of surviving such treatment. While the experiments of Luyet and Hodapp, Shettles, Shaffner, Hoagland and Pincus, and Parkes (1938–1945) were not successful in the retention of fertilizing capacity, they did retain the property of motility. The addition of glycerol to freezing media by Rostand (1946), Polge, Smith and Parkes (1949), Smith and Polge (1950) and Polge and Rowson (1952) (24) finally culminated in the retention of the fertilizing capacity of bull sperm stored at −79° C. for several months. The modification of the laboratory procedures for mass production as required for practical artificial breeding required the talents of uncounted workers—physiologists, chemists, physicists, glass workers, mechanics and businessmen to name a few. The fact that a large percentage of the dairy cows being inseminated receive frozen semen is proof we can solve the most difficult problems when we utilize the resources available to us.

Environmental Physiology

Day to day changes in the weather—which includes temperature, light, moisture, air movement and radiations from space, and the long range weather patterns which characterize a climate—have a profound effect on plants, animals and man. The climatic environment influences nearly every economic aspect of plant and animal agriculture, crop yields and composition, animal growth, reproduction, milk production, egg production, and the efficiency of conversion of feedstuffs to more salable products. During the nineteenth and early part of the twentieth century, man practiced the philosophy that animals should be adapted to whatever climate existed in a particular place. As a result, there are literally hundreds of breeds of livestock scattered over the globe. Many of these have been selected for local survival, but, unfortunately, the great majority of these breeds and types are of extremely low productivity. It is now apparent that there is an optimum climatic environment for every body function. There is a very good possibility that advances in technology will make it possible to alter or control a large segment of the environment and to more effectively meet the requirements for maximum animal productivity and efficiency.

Various aspects of environmental physiology have been discussed in reviews by Brody (1, 25), Lee and Phillips (26), Findlay and Beakley (20), Wright (20), Yeates (20). Literature citations to the studies mentioned here can be found in these reviews.

All of the higher animals are homeotherms. The maintenance of constant body temperature requires a delicate balance between the heat produced within the animal, the heat gained from the environment, and the heat lost by the animal to the environment. The early studies of Atwater, Armsby, Kellner, Forbes, Ritzman, Benedict, Brody, Kleiber, Mitchell and many others have given us an excellent background of the nature of heat production, radiation, evaporation, conduction, and convection. The studies of Meyer, DuBois, Hardy, Grant and others have shed light on the role of the nervous system, especially the hypothalamus, in the maintenance of homeostasis. The researches of Brody, Kibler, Thompson, Worstell and others at the Missouri Station, and Findlay, Goodall, Yang and others in Scotland have yielded a wealth of information on metabolic functions, cardio-respiratory activity, growth and milk production in cattle.

As would be expected, the great majority of the work has dealt with the effects of the environment on animal productivity. The observations of Rowan (1925) and Marshall (1937) that light appeared to affect reproduction in birds and sheep, and the report of McKenzie and Berliner (22) that the semen production of rams varied seasonally, encouraged other studies to determine the role of climatic factors in reproductive efficiency. Erb, Andrews and Hilton, Wheeler and Andrews, Sykes and Cole, and Mercier and Salisbury conducted studies to explain the seasonal factors associated with fertility in cattle, chickens and sheep. Yeates has had considerable success in altering the breeding season of sheep by controlled lighting, and Dutt has investigated the influence of light and temperature.

Rhoad, Seath and Miller, Payne, Laing, Minnett and others have made numerous observations on the grazing habits of animals of different breeds, and colors under different climatic conditions. One of the principal obstacles to the acclimatization of European breeds of cattle to tropical environments is their inability or unwillingness to graze in the sun. Kelly, Bond and Ittner at the California Station have markedly improved rate of gain in cattle by the use of various types of shade, cool water, and air movement. Heitman, Hughes, Kelley, and Bond, in a series of studies begun in 1949, have shown that the optimum temperature for growth and efficient feed utilization in swine weighing less than 150 lb. is about 75° F. and that for heavier pigs about 65° F., and they have studied heat and mositure loss from swine under a variety of climatic conditions. Newland, McMillen, Reineke, Thorp, and Laine found the newborn pig exhibits a sharp drop in rectal temperature shortly after birth and requires 2 to 10 days to develop an efficient temperature regulating mechanism. Field studies in Oklahoma, Indiana, Georgia, Texas, and many other areas have shown that some means of cooling swine during the summer months is essential for maximum

growth and efficiency. The systems being studied vary from hog wallows, and simple sprinkler devices to complete mechanical air conditioning or floor temperature control.

The investigations thus far carried out indicate that our farm mammals and birds are essentially cold adapted rather than heat tolerant. In most cases, as environmental temperatures rise above 70° F., our farm animals tend to reduce feed intake in order to reduce heat production. Since a high growth rate or high milk production requires high feed intake, there is a gradual decline in animal productivity and efficiency of feed conversion as environmental temperatures rise above the zone of thermal comfort. The area of environmental physiology or bioclimatology should be an important one in the next fifty years.

Speculation

When more becomes known about the chemical and physical regulation of growth, reproduction, and lactation, it may well be that we will look more favorably on the dual, triple, or quadruple-purpose animal. It is a certainty that present standards of growth rate and feed conversion will not remain static. We have previously believed that performance would ultimately reach the genetic limit of animal response. When we understand the nature of gene action, the response of animals, while not limitless, will most certainly be unbelievably extended. We should be able to increase not only the velocity of growth, but to exert a real influence on the growth of selected tissues. The enzymatic, or other means of meat tenderization, should allow us to concentrate on muscular development, if that is what the fickle consumer then demands. There is nothing incompatible between growth and milk secretion. The administration of hormonal materials now available has shown that full production may be achieved in the absence of pregnancy and that many an estrogen-treated steer or wether has shown at least limited milk secretion. It is conceivable that we may at last be able to achieve an efficient level of meat and milk production in one sexless animal.

The production of large numbers of fertilizable ova in cattle and sheep has already been accomplished, as has the transfer of the fertilized ova to other females. One of the major developments of the next half-century will be the achievement of sex control. The widespread use of artificial insemination and the preservation of the sperm of all species for long periods of time will greatly increase the desirability of producing sex to order. The meat producer will most certainly demand a high percentage of males unless the sexless all-purpose animal is produced first.

More disturbing than the above possibilities is the thought of controlled parthenogenesis—the production of normal young without fertilization. We have assumed that nature has limited this phenomenon to the lower forms of life. The studies of Olsen, Chang, Pincus, and others have shown that

many vertebrate ova cleave without fertilization, and in several instances, parthenogenic turkeys or rabbits have been hatched or born. If and when cleavage and normal development can be controlled in the absence of sperm, animals and man will face real social and economic adjustments.

The rapidly increasing pace of research should make the next half-century even more exciting and productive than the past.

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FIFTY YEARS OF PROGRESS IN MEAT RESEARCH

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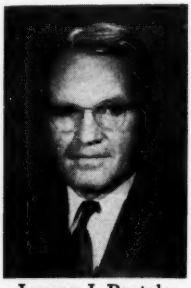
MEAT research has been an important part of animal production experiments for the last 50 years. At the beginning of this period, meat investigations were closely related to the nutrition and production phases of animal research projects. With the establishment of many new laboratories and the improvement of existing facilities in the last 10 years, meat researchers are at present more interested in the detailed technical considerations of their product. The continuous urbanization of our economy has resulted in a comparable increase in emphasis on the utilization aspects of animal production. The change in living conditions has been accompanied by a shift in consumer demand from volume meats to products that meet a more specific demand for convenience, rapid preparation and portion control. Present day competition for the consumer's food dollar has added importance to the necessity of evaluating the product of a feeding experiment by measures that are more inclusive than pounds.



Lyman J. Bratzler

In attempting to record the progress in meat research realized during the past 50 years, the author was aware that documentation of dates and credits may have resulted in errors of omission and commission. For all of them there is sincere regret. A rigid chronological record would require many changes in subject matter. In its stead, a broad classification of research categories was made, with each segment being discussed for the time period under consideration.

At the beginning of the 20th Century, considerable emphasis was placed upon home or farm slaughter. Formal animal husbandry courses in meat were presented from the producer's standpoint. Slaughtering, cutting, and preserving methods were the principle parts of these college courses. Bulletin titles, such as Meat on the Farm (1), and Dressing and Curing Meats on the Farm (2), indicate the attention given this phase of meat research up to 1925 or 1930. This can be contrasted with the title, Meat for the Family (3), that was published in 1947. The former bulletin allotted 15 pages of 36 describing the dressing operation while 17 of 100 pages of the latter publication dealt with the slaughtering phase and the remaining space embraced boning, cutting, knot tying, freezing, and sausage processing.

Carcass Evaluation

Beef. Carcass evaluation has interested the meat researcher for many years. In 1902, H. W. Mumford (4) described the market classes and grades of cattle that were used in trading on the Chicago Market. Grade terms like Prime, Choice, Good, Cutter, and Canner, found in this publication, are still in use today for describing certain slaughter cattle. Hall (5), in 1910, suggested a classification and grade terminology for all meats. U.S.D.A., or Federal grading of beef, as based on Hall's work, was given an industry trial in 1927. There have been gradual changes and refinements made in the grading standards and specifications which were based on the results of research and also on industry suggestions. The most recent (6) announcement lists five classes of dressed beef that may be grouped into some of eight grades. It is of interest to note that these include Mumford's grades in addition to Standard, Commercial and Utility.

Composition of the beef animal and its resultant dressed unit has received much consideration by the production and product researcher. Slaughter data have shown little change in number of items recorded. In 1912, the Illinois workers (7) took 38 different weights during the dressing operation. This compares with the 21 suggested by Deans (8) at a meeting of the Reciprocal Meat Conference in 1952. The problem of "fill" was recognized by the former group as shown by the following statement when the difference in dressing percentage between two steers was explained, "Had the weight of the undigested food in the stomach at time of slaughter been the same. . . .". In an experiment (9), "warm, empty weight" was defined as live weight minus the contents of stomach, intestines, and bladder. The present term of "empty body weight" has the same meaning. The problems caused by "fill" have not been resolved, although the practice of a 24-hour feedless period, but with access to water, as followed by the early workers, has been continued when the experimental animals are killed under laboratory conditions.

Separating the beef carcass into lean, bone, and fat was also done by the research workers in the early 1900's (7, 9). In the former, 71 retail cuts were made and divided into their component parts. In both experiments, chemical analyses for water, fat, nitrogen, ash, and phosphorus were made. It is interesting to note that an experiment (9), planned in 1909, had as one of its objectives the following: "How much, if any, too fat are feeders required to make cattle to satisfy the demand of the consumer?" In the other work (7), this observation was made, "there seems to be no relation between market prices and the percentages of fat, protein, extractives, and ash". The laborious task of physically separating a half or whole carcass was eliminated by Hankins and Howe (10), who established the relationship of the 9–10–11 rib cut to the entire carcass in respect to lean, bone and fat components. By applying the estimating equations developed, the investigator can determine with much confidence the physical composition of

the whole carcass and wholesale cuts if the composition of the 9–10–11 rib cut is known. Time saved by this short cut may be as much as 25 man hours per side of beef. Another method (11) that further simplifies the determination of carcass physical composition is by use of specific gravity determinations.

Chemical analyses of carcass composition have shown little change. Proximate determinations have always shown the inverse relationship of water to fat, and are difficult to use in explaining differences in live animal treatment. A standardized procedure for measuring beef carcasses was adopted by the members of the Reciprocal Meat Conference (12) in 1952. The origin of the revised methods can be credited to U.S.D.A. workers, probably in the 1920's.

Pork. Market classes and grades of slaughter swine and pork carcasses were suggested in 1910 (5). These were used primarily in reporting live prices, as the industry used weight averages for pork cuts and carcasses for trading purposes. Objective pork carcass grades were adopted by the grading service in 1952 and revised again in 1955 (13). Little attention by research workers has been given to the development of grade specifications for pork cuts as they are still sold, for the most part, on a weight average basis.

Interest in the composition of pork carcasses has been variable. During periods of national emergencies, when fats were in demand, little consideration was given to the proportion of lean to fat. Following these periods of fat shortages and combined with the decrease in demand for lard as a shortening agent, much emphasis was directed to the production of hogs producing more lean and less fat. The Illinois workers (14) in 1922–25 physically separated all the wholesale cuts from 189 pork carcasses into lean, fat, bone and skin. Nebraska workers (15) did the same with 60 carcasses. Physical separation of pork has had very little allure for the meat researcher. The modern investigator, for the most part, has confined his interest in physical composition to the wholesale cuts as a measure of carcass value. Classifying them as either "lean" or "fat" and deciding whether they should be related to the live or carcass basis has been the subject of much discussion. The problem of "fill" has not been resolved, but standard methods of slaughtering, chilling, and cutting pork carcasses were adopted by the Reciprocal Meat Conference in 1952 (16).

Much effort has been directed towards finding a single pork cut that would reflect accurately the composition of the entire carcass. Bureau of Animal Industry workers (17) found that the lean of the right ham gave a fairly reliable estimate of carcass lean. A coring technique (18) was developed by Minnesota investigators. Brown *et al.* (19) found that a close relationship existed between carcass fat and specific gravity. This technique has been applied by other workers to various cuts, in the hope of finding one that will predict accurately the composition of the entire carcass.

Early interest in the chemical composition of pork carcasses, as in beef, was from the nutritionist's viewpoint. Carcasses from 157 hogs at various stages of growth and fattening were analyzed for dry substance, crude protein (N X 6.0), fat, and ash by Mitchell and Hamilton in 1929 (20). The necessity of obtaining a representative sample of the entire carcass results in a product that has little value even if the bone is excluded. Because of the economic loss involved and grossness of the analytical results, the modern investigator has shown little interest in this phase of research.

Objective measurements of the hog carcass as indicators of excellence or value have been applied since 1922. In 1922–25 (14) seven carcass measurements were taken on 189 hogs of various types. Included was a measurement of backfat at approximately the 3rd thoracic vertebra. It is interesting to record the authors' comment regarding this dimension, "Depth of fat over the back, while an exact measurement, is not particularly important as it does not show the exact degree of condition. . . ." It would seem that one mark of progress in research is that nothing is taken for granted, because in 1934 the U.S.D.A. workers (21) applied 15 carcass measures that were developed in 1929 to pork carcasses and found a correlation of 0.84 between the average of 5 backfat measures and ether extract of the edible portion. Backfat thickness is one of the criteria used in determining the U.S.D.A. pork carcass grades previously mentioned. Hazel and Kline (22) applied this measure to live hogs and found that it gave a closer relationship to percent lean cuts than did the actual carcass measurements. This application has made it possible for the breeder to determine with a good degree of accuracy the fatness of potential breeding stock. A standard method of measuring pork carcasses was adopted in 1952 (16), which makes it possible for investigators to compare results between stations.

Lamb. The first suggested slaughter and carcass classes and grades of sheep and lamb were published in 1910 (5). While the interest in these grades was not as pronounced as in beef, the U.S.D.A. made them available to the research worker and industry at approximately the same time. The last revision was made in 1957 (23) and present grading is done on these standards and specifications. The intervening revisions were based on suggestions from industry and on research results.

The physical composition of lamb carcasses was intensively studied by the U.S.D.A. workers and the results published in 1947 (24). They simplified the task of determining both the physical and chemical composition of either the lamb carcass or individual wholesale cuts by developing estimating equations based on the composition of the 9-rib cut. The specific gravity technique has been used, but no conclusive relationships have been established. Chemical analyses for water, protein, fat and ash have been utilized, but not to the same extent as with beef and pork carcasses. The interest in muscling and leanness has received the attention of lamb producers and also of some meat investigators. The goal of a larger

rib eye with little increase in carcass weight appears to be difficult to achieve and offers a challenge to all interested researchers.

Lamb carcass measurements have followed the pattern of those developed for beef and pork. Standardized cutting methods and carcass measurements were adopted in 1953 (25). As in the case with beef, no single measurement or combination of measurements taken of the carcass have shown satisfactory relationships to grade or carcass composition.

Technical Problems

Tenderness. The tenderness of meat has interested many of the research workers in meat technology. The consumer has always desired tender, flavorful and juicy meat at the lowest possible cost. If the meat is tough, it is generally objectionable, irrespective of all other qualities, and it is this quality that has been studied with some success. Meat tenderness has been measured by mechanical, chemical, organoleptical and histological methods.

Lehman (26) described two mechanical methods for measuring meat tenderness in 1907. Another application of mechanics to this problem was described by Warner (27) in 1928. This instrument was redesigned and is now known as the Warner-Bratzler Shear. It has been widely adopted but is recognized as having certain faults. In the 1950's, a number of other instruments were developed and described which have much merit and await only extensive tests to determine their accuracy and ultimate acceptance (28).

The chemical analysis of meat constituents as a measure of tenderness followed the observation of Lehman (26) that tenderness was due primarily to the amount of connective tissue present. In 1928, Mitchell and Hamilton (29) published a method for the determination of collagen and elastin and the results obtained when comparing the effect of grade and sex on the amounts of the two proteins present in eight different retail cuts of beef. The method was modified by Kansas workers and considerable effort has gone into this determination by many investigators. It is generally agreed, however, that connective tissue *per se* is not the major factor responsible for varying degrees of tenderness. Recently more attention is being given to the muscle plasma fraction of meat by studying cation concentration and shift and also water holding capacity.

The application of taste testing meat for tenderness was begun by the members of the Conference on Cooperative Meat Investigations. The first score cards were detailed and too inclusive for most palatability committees and have been revised to allow for more precision in testing. Inasmuch as the final estimate of tenderness is made by consumers, the organoleptic determination by either trained or consumer panels has much merit, providing the number of samples or variables is relatively small.

The histological measurement of tenderness has received less emphasis

than any of the preceding methods. Size of muscle bundles and fibers, and their characteristics have shown some relationship to tenderness. Differential staining for connective tissue content has been disappointing as an indicator of tenderness. The extensibility of single muscle fibers has been studied by Wang *et al.* (30). Here again, a relationship to tenderness was observed but was not large enough to be used as a single measure.

Color. The color of meat is important from the standpoint of customer appeal and salability. One of the big problems in meat color was that of "dark cutters". Such factors as exercise, ration, slaughter method and handling conditions were studied as possible contributing causes. This problem was solved when it was found that prolonged periods of stress prior to slaughter frequently resulted in the production of "dark cutters" (31). Measurement of meat color has not proved to be an easy accomplishment. Methods used have ranged from the series of ten color paddles, disk colorimetry, spectrophotometric determinations of color absorption and reflectance to difference meters and various photometric adaptations.

Flavor. Interest in the flavor of meat has not been of particular interest to the meat technologist. The earliest work (32) indicated that the flavor of the raw product was confined to the juices, while the fibers were responsible for most of the cooked flavor. Due to the definite off flavors that develop when meat is irradiated, interest in this subject has been renewed. It would appear that the flavor of both the raw and the cooked product is concentrated in the water soluble portion of meat (33).

Cookery. The cooking of meat received much emphasis from the members of the Cooperative Meat Investigations Conference. Standardized procedures for the various kinds of meat cookery were established and since that time only slight revisions have been made. One of the major contributions was that of showing the benefits of low temperature cookery when applied to all kinds of cuts. The recent interest in outdoor cookery has not been transferred to the foods laboratory and hence, no procedures based on scientific evidence have been suggested.

Consumer Preference. Two disciplines, technology and economics, have been used to study consumer preference of meat. Little was done in this field prior to 1950 but since that time considerable effort has been expended to determine the likes or dislikes of the consumer. The relationship between grade and consumer preference has been explored with confounding results. The development of better techniques and more precise measurements in this field will provide the animal producer with valuable information relative to the type of animal most desirable from the consumer's standpoint.

Meat Processing and Distribution

Progress in the commercial meat industry has been continuous. One has only to visualize the scraping of all hogs by hand in 1909 and compare this

method with the modern automated hog dressing line of today in order to obtain some idea of the changes that have occurred during the past 50 years. Accurate documentation was difficult as very little of the research work done was recorded in the literature. In addition to personal communications (34, 35), considerable information was obtained from a meat industry publication (36).

Some of the companies bought their first motor trucks in 1909 for the delivery of meat to retail outlets. Improvement in refrigeration methods was rapid and refrigerated display cases were being installed in retail markets. At about this time there was some concern on the part of the legislative bodies regarding the wholesomeness of frozen stored meats. Compulsory dating of products was suggested, but the requirement was not enacted into law. The Packers and Stockyards Act of 1921 transferred the regulation of the meat industry from the Federal Trade Commission to the Secretary of Agriculture. The following year saw the organization of the National Livestock and Meat Board and in 1923 this group appropriated $8,000 for research to be done on the value of meat in the diet. From this modest beginning, the Board has been one of the foremost agencies promoting educational campaigns to counteract deleterious propaganda against meat.

Hormel and Company introduced the semi-sterile canned ham in 1926 and the same type luncheon meat in 1928. In between these two years, Federal grading of beef was given a trial and in the same year Swift and Company was the first packer to place a brand name or trademark on fresh meat. An Arkansas City packer reported success with packaged pork chops and frozen beef tenderloin in consumer sized units in 1929. The industry publication (36) made the following statement regarding this innovation: "The approach of the new era is heralded by two major influences—quick freezing and a code of fair trade practices providing for self-regulation of the industry." While the following year saw Swift, Armour and Cudahy marketing a small volume of frozen chops and steaks, the packing industry as a whole was not overly optimistic regarding this marketing method. At the same time, a few retail grocery chains were experimenting with centralized cutting and packaging of fresh meats. New approaches to the lard problem were tried in the form of hermetically sealed containers and the addition of lecithin to retard the development of rancidity. After continuing research over the years, the industry was convinced that the cause of sour hams and other cuts was almost entirely related to the efficiency of chilling and maintenance of proper temperature throughout curing.

Following the adjustments made during the early 1930's, Hormel and Company introduced their 12 oz. canned spiced luncheon meat known as "Spam" in 1937. The same year found the industry experimenting with cellophane and cellulose casings. Equally important at this time was the development by Wilson and Company of the mild-flavored ham which was

artery-pumped, cured rapidly, and then heat processed in the smokehouse to give a product which could be eaten after limited heating in the home. During this same period, Vogt Processes developed the Votator for the continuous plasticization of lard; the Dupps Company successfully applied solvent extraction to meat industry by-products, and Tobin Packing Company patented a strippable plastic for whole hog depilation. In 1939, the high temperature—high humidity aging of beef was developed by the Mellon Institute.

Swift and Company introduced their bland lard that was stabilized by using gum guaiac as an anti oxidant in 1940. Lard was redefined by the Secretary of Agriculture who announced that it could be made only from fresh pork fatty tissue. During the remainder of the 1940's, the meat industry was concerned primarily with the war effort. The new laboratories of the American Meat Institute Foundation were opened in 1949 on the University of Chicago campus with facilities for research in all phases of meat processing. One of the large grocery chains reported that the merchandising of packaged fresh meats had become practical and would be the accepted method of retailing meat in the future. A new device for peeling cellulose casings from frankfurters was perfected in 1950 as was the multiple needle injection method for rapid curing of bellies. Armour and Company announced a 40 item line of frozen foods and the production of ACTH had been increased 30 fold with a 50% reduction in cost.

Results of research since 1950 are many and varied. The immobilization of hogs prior to slaughter by carbon dioxide; use of ascorbic acid and related products for the rapid development of color in cured products; enzyme tenderization of fresh meat; the use of phosphates in curing to increase yields; the on-rail dressing of beef; the introduction of complete lines of packaged frozen meats for the institutional and retail trade; and the gradual de-centralization of the meat industry in general have been highlights of progress in the present decade. In addition to the ever present profit picture, it would appear that the matter of "humane slaughter" is the most pressing problem confronting the industry at this writing.

Forecast for the Future

The insistent demand of the animal producers and breeders for a method of evaluating the live animal in terms of carcass characteristics will be satisfied. Specific gravity determinations *in vivo* by air displacement, measurement of tenderness on small biopsy samples, and the estimation of muscling by ultra-sonics show promise of aiding the geneticist to select those individuals that have the desired characteristics and thereby hasten the improvement of all livestock. The freeze-dehydration of meat will provide maximum nutrition with a minimum of bulk for our mobile Armed Forces and also consumer items that will not require refrigeration. The same process will allow the technologist to preserve his samples for later examination and analysis with very little change in physical characteristics after rehydration.

The identification and solution of the flavor problem will make it possible for irradiated meat products to compete with canned meat items on the grocers' shelves and for the consumer's food dollar. The application of flavor and tenderizing principles will shift the present emphasis on eating quality to the volume or quantity basis. With this change will come the more efficient utilization of the lower grades of livestock to provide an increased variety of meat products for the American family. Livestock handling and slaughter methods will be improved. Meat will be cut, trimmed, packaged and frozen by the processor or in large centralized units for distribution to retail markets. Each segment of the meat industry from producer to consumer will benefit from future progress. The horizons are unlimited!

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FIFTY YEARS OF PROGRESS IN LIVESTOCK EXTENSION TEACHING

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PROGRESS in extension work in livestock teaching is a reflection of the progress in research work. The Smith-Lever Act, enacted by Congress in 1914, provided that cooperative agricultural extension work shall consist of the giving of instruction and practical demonstrations to people who are not attending colleges participating in the Act in the several communities. The information imparted to these people was to pertain to agriculture and home economics and related subjects. It was expected to be practical and useful and provided in a manner agreed upon by the Secretary of Agriculture and the State Agricultural Colleges.

W. G. Kammlade

Hence, livestock extension work is essentially an out-of-school system of education in which adults and young people learn by doing. That extension work in animal husbandry could not reflect all of the research work that has been done is easily understood. Much of the work done in research laboratories does not yield results which are immediately applicable or of current practical value. Thus, there may be some time lag between research work and the use of the information. This is frequently deplored by those who overlook the need for research and information on which to base later practical applications. Furthermore, there often is a very significant difference between the difficulties which may be encountered in doing research work and having the results of research widely applied or adopted. A research undertaking is usually a unit. Frequently the same type of research work is carried on in many different institutions. Results are not always in complete agreement. This is not a criticism. The purpose of research is to learn the results of a particular study. To get results applied by the millions of livestock farmers is quite a different problem. The application of the results relating to farm animals has a bearing upon the already established operational details of the

[1] While I have not found it possible because of limited space to quote directly from very helpful letters and publications received, I have tried to weave into this review the gist of ideas received. I must especially thank Rex Beresford of Iowa, W. W. Derrick of Nebraska, A. C. Esplin of Utah, Claude Harper of Indiana, Grady Sellards of Kentucky, Lawrence Kauffman of Ohio, and H. G. Russell of Illinois.

enterprises and the farm organization, as well as the understanding, of the farm operator. It would seem to be relatively easy, for example, to discontinue the use of pastures in producing hogs and to put all of the hogs in a proposed modern, mechanized, pushbutton hog-producing unit. If one does not understand all that is involved, he could be quite critical of the time lag in making such a change. There are a large number of factors to be considered by farmers before the adoption of any such recommendation even though the physical changes involved could be made readily.

If livestock extension work is related to research work then anyone who knows the kind of research work which has been done in our agricultural experiment stations during the last half century will know to a considerable extent the efforts which livestock extension workers have been making and what types of information they have been providing to farm people. The information must meet the needs of the people who are producing, maintaining or marketing animals or are otherwise engaged in activities relating to animals. Many of the things which have been done are not easily documented and a history of livestock extension work in the United States is an undertaking far beyond the intent of the present paper. In a brief review only a few items can be considered.

Forerunner of the Extension Service

Livestock extension, like other extension work, did not become formalized by legislative enactment until 1914. Prior to this, however, there were many activities of an extension educational nature. There were organizations of many different kinds, the purposes of which were largely educational. For example, farmers institutes were one of the forerunners of extension work. Institutes were held for a full half century before the passage of the Smith-Lever Act which established the Extension Service on the basis that it is known today. Institutes were held in many different localities. They related to such subjects as cattle breeding, butter making, egg production, hog feeding, etc. Certainly the information provided was greatly different from that which is given today. Along with the farmers institutes, county fairs, and other types of activities, the agricultural colleges undertook, somewhat independently, various types of extension work. This effort involved such matters as demonstrations of various methods, the preparation and distribution of publications, and of writing for newspapers and farm publications.

Pioneer Extension Leaders

The history of agriculture includes many references to the pioneering work of Seaman A. Knapp and his development of the demonstration method of teaching. This method was used extensively by the early livestock extension workers. It is still used and is one of the most effective ways of doing extension work. Essentially it consists of getting some pro-

ducer or group of producers to undertake the application of some of the results of research in connection with their livestock production programs. If these people find the information useful and valuable, then what they have done is used as a means of teaching others.

Fifty years ago extension work pertaining to animals was conducted largely by farmers' organizations. There was not the highly organized Extension Service with an administrative staff, specialists in various aspects of livestock production, representatives of the Extension Service in counties, and so on. There were no organized channels through which information could flow from the experiment stations to those desiring the information derived from research. Prior to the development of what might be termed "intensified or extensive livestock research", what had been learned by experience was taught by the most successful livestock farmers to others through writing or publications or through participating in farmers institutes and other meetings. Today the livestock extension worker uses successful experience of livestock producers, marketing associations, etc. as a part of his extension educational materials.

Successful experience and the understanding of it are very important elements in extension teaching. Before extension work became organized some farm groups employed farm advisers. This may have been true in a considerable number of states but so far as the writer is aware there is no documentary report showing the extent of such activities. In Illinois a number of counties had employed people on the basis of contributions from farmers, bankers, and others interested in farm progress before the Smith-Lever Act was passed. This Act provided for the employment of what are commonly known as "county agents" or "farm advisers" by the United States Department of Agriculture, the State Land-Grant College, and either local groups of farmers or local county governments, cooperating. But there were 14 so-called "county agents" or "farm advisers" employed in Illinois to assist in agricultural development in all its aspects before the passage of the Smith-Lever Act. Some other states had similar services. The college was chiefly an advisory organization so far as this effort was concerned. Most of the meetings were open to the public but in some cases the members thought that they had special rights to the information which the employees could provide.

Several of the agricultural colleges had organized agricultural extension divisions prior to the passage of the Smith-Lever Act. Apparently the leading states in the development of extension work were New York, Illinois, Iowa, Indiana, and Texas, where Seaman A. Knapp performed his first demonstrational work. Knapp's work, however, did not relate to livestock. Other states followed shortly and the claims to priority are of little significance.

Twenty-five years before the Smith-Lever Act was passed J. S. Newman (1) of Alabama speaking at Knoxville, Tennessee, remarked that "Farmers, like other people, hesitate to believe and act on theories or even

facts until they see with their own eyes the proof of them in material form. We must in some way bring this work to their personal attention. We must carry it home to them. How are we to do this is the most important question for us to consider".

One of the earliest mentions of extension work relating to livestock in any way was made in a report for the year 1894 by E. B. Voorhees (2) of New Jersey who spoke on the attitude of the college toward extension. In describing what he said they were calling in New Jersey "agricultural extension work" he mentioned that this consisted of 6 lectures on 1) soils and crops; 2) feeding plants, and 3) animal nutrition. Perhaps this has some relationship to the early designation of the American Society of Animal Production as the American Society of Animal Nutrition.

At a meeting of the Land-Grant College Association in 1905 J. H. Hamilton (3) of the Office of Experiment Stations of the U. S. Department of Agriculture, talked about the Land-Grant Colleges standing as the "open door" for the 28,000,000 agricultural people. Among the duties of these colleges he listed that of serving the educational needs of farmers, pointing out that they were never greater than they were at that time. He also pointed out that "however much the colleges may have done for farmers in the past, or may do in the future, for the aid and elevation of men in their several pursuits and professions of life, they have signally failed with the main purpose of their creation if they have neglected to do for farm people not all that farm people need, but all that modern knowledge in agricultural science has made it possible for them to do". He insisted that the command to these institutions is to teach. They have a fixed location but their commission to give instruction is not bound by classroom walls. They were founded to promote the liberal and practical education of the industrial classes. He asked, "Where are these classes?" and answered by saying, "For the most part, they are out at work."

College Committee to Study Extension Work

Few people are aware of the great amount of preliminary work and study which preceded the enactment of the Smith-Lever Cooperative Extension Act. The Land-Grant College Association had a committee for a number of years studying the problem of extension work. The report of the committee appointed in 1905 was made at the Land-Grant College Association meeting in 1906. For five years this committee continued to study and make significant and comprehensive progress reports. The chairman of the committee was Kenyon L. Butterfield (2), President of the Massachusetts Agricultural College. Other members of the committee appointed in 1905 were Charles R. VanHise, President of the University of Wisconsin; Charles F. Curtis, Dean of Agriculture at the Iowa State College; Andrew M. Soule, President of the Georgia Agricultural College; W. M. Hayes of the U. S. Department of Agriculture; and B. W. Kilgore, Dean of Agriculture

of North Carolina Agricultural College. The reports of this committee relate to almost 40 different topics and methods concerning the organization, development, and importance of extension work in agriculture. Although livestock is not often mentioned specifically, these reports were very significant in the considerations leading to the passage of the Smith-Lever Act. The 1906 report contained the following recommendations:

That each college represented in this association organize as soon as practicable a department of extension teaching in agricultural work, with a competent director in charge, and with a corps of men at his disposal. It was recommended that this department should take on all phases of extension teaching now performed in other ways. The committee hoped at some future time to suggest a scheme of organization and effort which would be applicable to most institutions. At that time it merely advised this initial and all-important step—that of having an official whose chief business would be to foster, to systematize, and to organize for the institution all phases of extension it might assume.

The 1908 Report. Other recommendations related to the appointment of committees in each institution to study how the extension activities could be made feasible and a definite organization provided. In its 1908 report this same committee recommended appropriations by the national government to each state, and additional state appropriations to be used as off-set funds for the appropriations by the federal government. In its report the committee said:

"Your committee desires first of all to emphasize with all possible vigor the pressing need for organized work at the agricultural colleges of this country by means of which the colleges may more completely reach the working farmers. There is need of more effectively reaching the young farmers at home and in the rural schools.

"Furthermore, the work of disseminating agricultural information is at present not only inadequate in amount but it is also desultory and unorganized. There is no state in the union that has a thoroughgoing system of extension teaching compactly organized, adequately manned, covering the working forms of extension teaching and designed actually to reach out a hand to the larger proportion of the men and women and the youth of the farms. Your committee believes that the time has come when this problem should be met squarely and that steps should be taken at once by all of our colleges to organize properly equipped departments for this type of work".

Later in the report this committee says, "May we call the attention of the members of this association to what is perhaps a fanciful idea but also a rather suggestive one: In 1862 the federal government made its first munificent grant to the agricultural colleges. In 1887, 25 years later, it established its first formal aid for research and experimentation which has revolutionized our agriculture and our agricultural education. May there not be some point in the plea that by the time another quarter century has rolled around we shall see another federal appropriation for this third great phase of agricultural instruction which must be performed by agricultural colleges—for extension work?"

It was becoming ever more clear that the results of the research work which had been done by the Bureau of Animal Industry of the U. S.

Department of Agriculture and by the Experiment Stations were of little value in promoting a more progressive agriculture unless some means was established whereby these results were made known to farmers. The farmers then made progress by putting such results into use if they proved of practical usefulness in improving livestock production.

The changing character of the agricultural population and the perpetual flowing current of new workers to agriculture made it important that there be a source of information to provide an understanding of the best methods of livestock production and other aspects of farming. There had been such rapid strides in the knowledge of agricultural science that even the graduates of agricultural schools and colleges needed to continue their studies.

The Extension Service soon came to devote a great deal of its time to correspondence, teaching better educated farmers to avail themselves of the opportunities to keep abreast of the times. Even if others endeavored to reach the great mass of farmers, the Extension Service could find ample scope for its energies in higher forms of extension teaching. The extension services had the assistance of a great many commercial agencies who soon learned that if they were to be successful and continue to be so, they must have their products conform to the latest teachings of the extension service based on the results of research work, either in the U. S. Department of Agriculture, the Land-Grant Colleges, or comparable reliable research organizations.

Progress from Simple Beginning

Looking back over 50 years of livestock extension work, some of the early efforts appear very feeble and crude in terms of today's facilities for communication and travel. Today's results may seem equally ineffective when reviewed after the passage of another 50 years.

One of the fundamental principles of extension education relates to the situation of the people. The work must be done with people in the situations surrounding them. If, for example, a man does not know how to dock a lamb, then he needs to be taught how to do it if that is a part of successful sheep production. If he does not know how to shear a sheep, then he must be taught or he must employ someone to do the work who does understand it. If he does not know how to balance a ration in the light of the knowledge existing at any particular time, he must be told how to to so.

Today it is hard for many people to think that we did not always have tractors for horsepower. Many years ago livestock extension workers had to teach farmers how to fit a horse with a collar, how to take care of the harness, how to work horses to avoid lameness, shoulder sores, fistula, and many other common ailments, and how to hitch 4, 6, 8 or more horses so all would have an equal load to pull. These and many others were the problems with which the farmer or the livestock producer was faced. He had to start making progress in relation to these simple things before he

ever could get to the point of using antibiotics, hormones, complex feed mixtures and all of other other devices developed through research and which are recommended for his consideration today. Compared with a ration of timothy hay and oats for a beef steer, or a ration of corn, salt and water for a pig, rations made up of several different grasses and legumes and 3 or 4 varieties of grain, become rather complex developments. Likewise, the latter appears relatively simple compared to the multiple ingredients in today's livestock rations.

Why do livestock extension workers teach about these complex rations at the present time? Because these have been developed and have been proved to be superior in nutrient content, in promoting animal health and in economy. However, what is recommended today as a result of research may become obsolete and outmoded relatively soon. It was not many years ago when the so-called "trinity mixture" (trio mixture, 50 lb. tankage, 25 lb. ground legume hay, and 25 lb. linseed meal) for use as a supplement to corn in feeding pigs was considered by many to be an outstanding improvement, but today one seldom hears of this being advocated by livestock extension workers in the most important hog producing states. But the use of the "trinity mixture" when modern supplementary nutrients were not readily available represented a considerable advance for some who were producing hogs.

One of the very significant differences between research work and extension livestock teaching pertains to what is involved in the two fields of activity. Research work may be conducted with a group of animals or an individual animal or with the products of animals to learn facts relating to these animals or their products without involving many people. When it comes to teaching what has been found out, then we come to a very significant difference and one of the most complex problems relating to any teaching effort. Research work may be done with things. Extension work must be done with people.

People—Fundamentals of Extension Teaching

People, their situations, their attitudes, their ambitions, their motivations, their abilities, their financial situations, and a host of other factors cannot be overlooked as the basic elements in extension teaching. Furthermore, there is a great difference between resident teaching and extension teaching. In the one case the class is one of formalized, compulsory attendance or captive audience, and those enrolled are expected to study and learn and pass examinations. These things do not have any significance for extension teaching which is done on the basis of voluntary participation. In extension the students are the livestock producers, the marketers, the processors, or, in some cases, the consumers of the livestock products. Perhaps it is more significant in a review article of this type to point out some of these things than it is to document a certain effort with a certain man or at a definite time.

In livestock extension there are many things which cannot be taught by demonstration. These things relate to such matters as the economic outlook, the problems relating to cooperative marketing, problems of processing, problems of consumer relationships, and so on. This is new, relatively speaking, in extension work in livestock production. Earlier the people who served as extension agents, farm advisers, or field agents, were expected to be practical farmers and little more. There was no use, for example, "in sending a carpenter to tell a tailor how to make a coat, even if the carpenter is pretty well read up on coats". The tailor wouldn't follow the teaching of the carpenter. The farmer wouldn't follow the teaching of anyone who did not know how to handle a plow, how to harness a horse, and how to do all of the practical things.

Farming by Signs Dispelled

Many farmers had peculiar views—peculiar in the light of our present day knowledge and understanding—but not peculiar in relation to widely held views 50 or more years ago. Many of them "farmed by the moon". Farmers who believed in the influence of the moon and the various signs of the zodiac being more favorable for certain operations, and who had not seen careful demonstrations showing that doing these things without relation to the moon brought just as good results, were not going to accept very much of an extension teacher's effort. Often it is necessary to disprove an old belief before a new one will be accepted. For example, often it was very difficult to get a farmer who was used to castrating his pigs in a certain sign of the moon to discontinue doing so. If he had "bad luck" following this operation in a different sign of the moon he did not assign his "bad luck" to neglect of sanitation. To displace such beliefs and practices has taken a long, long time. In fact, the job is not yet done in all areas.

Another thing which has occurred in 50 years is the almost complete replacement of our earlier generations of people. Many people today have a vastly different attitude toward education in general. This is reflected to a great extent by those with whom extension is now working. Many farmers believe that progress and permanent help come from human effort and they must, like others, work out their own salvation.

Methods of Extension Teaching

Fifty years ago an extension worker's value was measured by what he could do; today his value is measured largely by what he can get other people to do. Thus there is a great difference between the type of abilities needed today by the extension worker and those needed 50 years ago. There is also a great difference in some abilities which the extension worker must have compared with some of the abilities needed by the research worker. Most of those in research must have great capabilities to design studies and to do the work themselves. Often, of course, they do have graduate students and assistants whom they guide and direct. The exten-

sion worker's value, however, is to induce other people to do things themselves under their own guidance after they have received the suggestions as to how they might improve their operations relating to livestock production, produce a better product more economically, and derive more profit from doing so.

The present day tools used in livestock extension work are similar in some respects and greatly different in others when compared with those of earlier periods. Earlier the only things available in livestock extension work to use for demonstrations were the farms on which various practices were being put into effect. Transportation was a problem. Today the networks of highways and methods of transportation make it relatively easy for livestock producers to travel and to see, study and learn, and the extension worker can transport many of the so-called "visual aids" which could not be used earlier. One of the earliest types of visual aids was the so-called "cow-sow-and-hen-special" which extension services used in various states in cooperation with the railroads. These "specials" consisted chiefly of railway cars in which were to be found various materials, including animals, feeds to make up rations and usually various types of equipment. Today as a part of extension work there are many special activities at colleges where farmers may come quickly to view the results of a particular experiment at the moment, almost, when the experimental work is completed. The animals are on display, the scientists are there with the statistical significance of the results of their efforts, the farmers are told about what was done, how it was done, why it was done, and what results were achieved. Some have visited the colleges frequently to follow the progress of the work. Some put the results of the work into effect on a trial basis almost immediately. Similar trips were made by some farmers years ago, and sometimes groups camped at the college for a week to listen and discuss and observe some of the work underway in the experiment stations.

4-H Club Work

One of the things which has had a great influence in livestock extension work has been the work with boys and girls through 4-H Clubs. Many adults have made greater efforts to improve, not only the operations of their farms, but to continue their education toward greater understanding and more significant citizenship, because of the efforts their sons and daughters have made in connection with 4-H livestock production. This work culminates in the great fairs and expositions associated with livestock. Through these events millions of people have become aware of the research and extension work of the Land-Grant Colleges and of the U. S. Department of Agriculture and have been motivated to strive for livestock improvement.

Accomplishments of Livestock Extension Work

The main business of farmers has been production. Livestock extension work related chiefly to the problems and opportunities associated with production. Extension teaching made important contributions to livestock production by informing farmers about selection, breeding, nutrition, physiology, sanitation, the control of diseases caused by bacteria and otherwise. The possible losses of animals were reduced through work relating to the control of insects, parasites, and so on.

The conquest of bovine tuberculosis in the United States is an "extension accomplishment" of immeasurable value. The leadership in this tremendous undertaking was provided by a charter member of the American Society of Animal Production. Howard R. Smith (5) demonstrated the value of persistent education, the development of understanding and the need for cooperation. Some very effective and beneficial extension work is done and has been done with the financial support and personal participation of members of commercial organizations and of organizations "not for profit". The almost complete eradication of bovine tuberculosis, an example of such work, is a blessing to man resulting from research and the discovery of the tubercle bacillus by Dr. Koch followed by the tuberculin test and later by meat inspection in slaughter plants. The extension service did not work at the eradication of bovine tuberculosis alone. Hundreds of organizations and thousands of people helped. Opposition was often violent. It is credit enough for extension to know that it had a part in the educational work that has reduced the scourge of tuberculosis from our livestock herds and diminished the hazards to humans at the same time. The difficulties encountered in motivating some people to engage in a program of such great benefit are illustrative of the problems confronting livestock extension personnel.

Better sire campaigns have been conducted in every state. Some have been more highly organized than others and some have been widely publicized. In these efforts the extension service has had the active support of producers of purebred livestock and their associations, of fairs and expositions and of many marketing agencies. The goal has always been a higher grade of commercial product. That extension workers did not always advocate the best type of sires to produce such a result in the most economical manner is not the fault of the extension personnel alone. Only relatively recently have research workers presented to extension staff some guides to selection and breeding which are being used to replace what was scoffed at but not improved upon. Breeding programs have not always worked as planned but neither have rockets.

The enthusiasm and devotion with which livestock extension teaching has been conducted is illustrated by the desire of the staff (6) in Union County, Kentucky, to have Union County become the first county in the

United States to have only purebred sires in use. One farmer steadfastly refused to discard and replace his scrub bull. Persuasion and pleading having failed, the county agent—with some good neighbor assistance—one night shot the scrub. Progress is thus sometimes contrived in strange ways. A monument to the last scrub bull for Union County, Kentucky, has been erected in the County Court House Square to commemorate the event and to permit all to see and learn.

Many projects have yielded benefits of great financial value to farmers. An example of such work is the "McLean County System of Swine Sanitation". This project was developed by Dr. H. B. Raffensberger of the U. S. Bureau of Animal Industry and stressed by Professor E. T. Robbins (7) of Illinois. It was devised after thorough studies of the life histories of several of the most common parasites and diseases of young pigs. It required simple equipment and relatively easily performed procedures used in connection with pasture rotation which fitted in well with common crop practices in Illinois. It was first used in 1919. Six years later 608 farmers were enrolled as cooperators. One hundred and fifty-four farmers reported as many pigs as usual from one-fourth fewer sows. Followers of the system raised from 1.7 to 2.7 more pigs per litter than non-followers and their pigs reached market weight seven weeks younger.

Marketing

Although livestock extension has often been accused of over-stressing production and neglecting marketing, this is scarcely supported by the facts. H. W. Mumford, formerly Director of the Extension Service in Illinois, served as Chairman of the "Committee of Fifteen" which devised a system of cooperative livestock marketing associations which have functioned effectively for many years.

Among the livestock and livestock products which have received much attention from the marketing standpoint are lambs and wool. There have been hundreds of lamb grading schools and marketing pools. Constant efforts have been directed toward improvement in feeding to produce a better market product. Castration, docking, parasite control and many other items have been stressed. Better shearing, better handling of the fleece, selling on the basis of class and grade and on the "core test" for shrinkage have not been overlooked. Wool marketing work received much attention in many states—more particularly in the western areas. The list of names of men associated with this work is too long to mention. It is sufficient to say that shearing, fleece preparation, grading, packaging, for market, and organizing and financing wool marketing cooperatives or pools locally, regionally, and nationally were not overlooked. Pools might include a few hundred fleeces or might be made up of over a hundred thousand fleeces. In some cases woolen mills were active cooperators and during periods of low wool prices made growers' wool into blankets at cost and returned them to growers to sell.

Obviously in a nation as large as the United States there are at least as many programs of livestock extension work differing to some extent in their details as there are counties in this nation. For it is in the counties where the contacts are made with the producers. It is in relation to their situations and problems and opportunities developing from or in association with these situations that the extension work must be done. Even though this is true, changes must come in all plans because of changes in situations.

It is not unusual for emergencies to develop in relation to livestock and as Dean Liberty Hyde Bailey of Cornell once said: "Unforseen events change the constitution of human relations and make said projects impracticable and often dangerous. We need beacons more than programs, and extension needs to give direction more than to give directions".

Training of Extension Leaders

Training or preparation on the part of individuals to undertake livestock extension work has also undergone many changes during the past half century. It has already been intimated that "how to do certain things" was the criterion by which farmers judged the extension worker. Subject matter information has been and is, and always will be important, for farmers seek facts and suggestions based on facts. But the extension worker needs to understand far more than the facts relating to any particular problem. He needs to understand much about people, how to work with them, how to stimulate their efforts, to understand what makes people respond, how they are motivated, and what their aims and desires may be. He needs to be a type of person who has not only the personality, but the training, to act in such a way as to inspire confidence.

At one time it was important that the extension worker in livestock be a competent judge. This is a great asset today but he also needs to understand judging, not only on the basis of the physical appearance of animals, but judging or selection based on records of performance, efficiency in feed utilization, rate of growth, and the amount of nutrients to produce one pound of livestock product. All of these things relate to the training necessary now for the livestock extension worker compared with the earlier situation. Today the livestock extension worker is confronted with problems, not only in nutrition, physiology, genetics, balanced rations, etc., but many of the economic aspects of livestock production. Integration, brought about by the developments in connection with poultry, is now a very common subject of conversation. Many livestock farmers, marketing agencies, processors, and distributors, are seeking information not only from livestock extension workers, but from many others about the possible benefits and hazards and the possible consequences of integration.

The extension worker in livestock production is not a merchant of dead yesterdays but a guide into unborn tomorrows. They do not put conformity to old customs above curiosity about new ideas. They are not only endeavoring to make those who follow their teachings clever competitors in the

world but they are also trying to make them into creative cooperators. Extension in the next fifty years will progress as more knowledge about present and future problems and opportunities becomes available to teach those who want to learn. The friendly greeting and handshake given by the livestock fraternity to the extension man has been and will be the symbol of full value received.

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FIFTY YEARS OF PROGRESS IN TEACHING ANIMAL SCIENCE

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Introduction

HISTORY is but a record of the ebb and flow of human social force. For every person or class who rises, many are obliterated, either by destruction or absorption (4). Neither agriculture nor teaching have escaped that attrition. As a matter of fact, neither agriculture nor teaching have enjoyed a rising status in political or social affairs since the beginning of the Dark Ages. Agriculturists have been used traditionally as a means to an end by another more powerful social class. Teachers have been content always to follow rather than lead the tenets of social forces dominating a particular era—always striving to perpetuate tradition —always challenging a rising class (6).

L. E. Washburn

By 1908 most of the history of progress in the teaching of animal husbandry had been written. From that time until "Sputnik", teaching passively developed in the ignominous direction of training students to do what they liked rather than to understand and like what they did. Also, teaching nearly everywhere became subordinated almost to the point of extinction to research, more research, and finally to coordinated "projectitis". Consequently, to acquaint the reader with the fact that at one time a substantial program in animal husbandry teaching did actually exist, it is necessary to review briefly some events which developed prior to the founding of our society.

At one time agriculture was highly esteemed and ranked with military duty as an occupation worthy of a free man. That fact is well authenticated in the Old Testament. During the period from 800 B.C. to 400 A.D., the teaching of agriculture was given a position of importance by great literary figures including Hesiod, Xenophon, Theophrastus, and the Romans: Cato, Varo, Virgil, Columella, the elder Pliny, and Palladius. Agricultural controls were originated neither by the New Deal nor Secretary Benson, but rather they were instituted by Diocletian approximately 2000 years ago (14–15). About 450 A.D., when the Roman empire was subjected to the onslaughts of barbarian hordes from the north, agriculture sank into a

condition of neglect, and never again was to command a position of political dominance (15).

Following almost seven centuries of the Dark Ages, the discovery of the Pandects at Amalfi in 1137 A.D. opened the Renaissance, an encouraging new epoch in the life of mankind. In the relatively pleasant environment of that period, a vigorous rebirth of two ancient social classes occurred. One class consisted of manufacturers, merchants, and capitalists. The other class embodied the artisans whose guilds were the forebearers of organized labor. Through "peaceful coexistence", the merchant class absorbed—at least temporarily—the labor class to form a strong commercial class. That social stratum won increasingly the favor of the church and crown. Taking advantage of the technology which arose from great scientific achievements of the period, those people initiated the Industrial Revolution, and forced agriculture into a position of servitude.

Man's desire to learn was reactivated by the relatively mild climate of the Renaissance. A number of the great universities were founded during the fifteenth and sixteenth centuries. In the new world the Universities of Mexico and Lima were established in 1551. The universities of the times, however, were appendages and instruments of the church. Curricula dominated by ecclesiastical policy, nonetheless, did offer the two divisions of study that composed learning: the trivium and the quadrivium. The former consisted of grammar, rhetoric, and logic. The latter embodied arithmetic, geometry, music, and astronomy. Beginning in Italy, but spreading soon to Germany in the north, teaching adopted the more practical aspect of education and social betterment. Even with these advances, nevertheless, teaching was still dominated by theological thought. In the more challenging climate of the north the first agricultural college was to be established later (14).

An event of major proportions occurred in 1517 which eventually was to effect all phases of life. This fact suddenly crystallized the world social order. It began with Martin Luther's apathy towards the selling of indulgences in order to gild the dome of St. Peter's Cathedral in Rome. It ended with the Reformation. Printing had been invented in 1440, and this vehicle coupled with religious cleavage introduced humanity to the great power of the press. As a result of these two occurrences, teachers had an opportunity to demonstrate their typical and disturbing trait of conforming non-conformity. These happenings bewildered the ruling heads, for religious freedom questioned the hereditary "divine right of kings". As a result the masses were frightfully persecuted. Taking advantage of the existing confusion, and proceeding on the calculated risk that the world was spherical, the industrial revolutionists sought to expand their perimeters of trade. The era of world colonization thus dawned.

Tudor England, to which America is hereditarily so greatly indebted, was confronted with a three-headed monster that embodied religious

indecision, industrial revolution, and civil representation in Parliament. Unbelievable as it may appear, however, out of that complex array of forces evolved much of our modern agriculture, animal husbandry, university administration, and indeed much of our total social spectrum. The social structure of England during the sixteenth century consisted of these classes in descending order (6):

1. *Crown—Church and Universities.*
2. *Landed aristocracy:* Titled owners of lands confiscated from the church. This group contributed moderately to future animal husbandry.
3. *Landed gentry:* Untitled owners of lands confiscated from the church. This group contributed largely to future animal husbandry.
4. *Merchants, tradesmen, capitalists:* The industrial revolutionists. This group contributed to animal husbandry in significant measure, but only insofar as their primary business was enhanced.
5. *Yeomen:* These were small free-holders beneath the rank of gentlemen but above the grade of laborers.
6. *Farm tenants, artisans, day laborers,* and *servants.*
7. *Dependent poor, beggars, vagabonds, thieves,* and *criminals:* This group composed approximately one-third of the population.

The combined pressures of increased demand for wool by the manufacturers and Parliamentary reapportionment by the citizenry resulted in the passage of the Enclosure Act. This act and its later modifications cemented the pattern of agriculture as we know it today. With the advent of the Enclosure Act feudal barons exchanged hunting and jousting for husbandry; freeholders and gentlemen became jointly concerned with land classification and use; and, "every maiden took to the loom" (4).

In an environment where deans operated concurrently as teachers, university and ecclesiastical authorities, and advisors to the crown, there developed certain techniques of administration which to this day have proven very useful to policy, but frequently rather inhibitory to educational progress. We recall with interest, for example, that university authority rendered the desired decision that permitted Henry VIII's divorce and subsequent marriage to Ann Boleyn, thus interrupting the long and frustrating actions of Cardinals Wolsey and Campeggio. Tudor England, however, did have a signal advantage over modern America in that mistakes were corrected with clean-cut finality at the block.

America, the colonial bridgehead, was established, consolidated, and expanded not by agriculturists but by the industrial revolutionists. The colonists were a cosmopolitan mixture of merchants, tradesmen, nonconformist clergymen, and lastly artisans who were needed for the construction of houses, churches, ships, harbors, and implements. They were religiously devout people endeavoring to escape persecution. These people were accompanied by a minority of adventurous nobility who had been carefully selected to insure sovereignty of the crown. Animal husbandmen were noticeable only because of their absence from the colonial passenger

lists. There was no need, after all, for the migration of animal husbandmen who enjoyed the status of landed gentry and aristocracy. Each colonist had his tract of land, and operated it as a general farm solely for the purpose of producing food and clothing for his family. He had a few sheep, milk cows, pigs, and chickens, and produced some grain, hay, and fruit. His primary interest, however, was not agriculture, and he derived his main income from a trade or as a merchant or manufacturer.

Occupying a narrow strip of land that lay between an ocean and an unfriendly wilderness, the citizenry needed most the wagons, tools, housing,

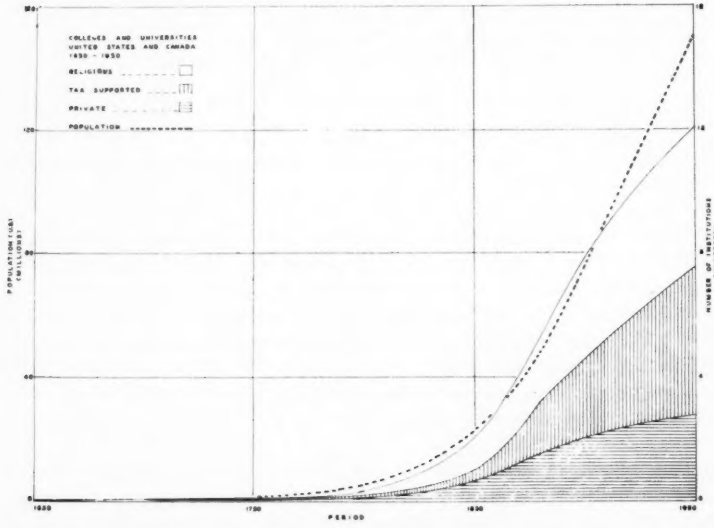

Figure 1. Growth in Number of Institutions of Higher Learning in the United States and Canada. 1650–1950 (2, 6, 11, 14). (In 1957 the United States alone reported 1857 institutions).

firearms, clothing, and whiskey, representing consumer goods and services of the commercial class. The creation of that commercial deity, the "Great White Father", was vastly more important to early America than were ideology, religion, education, or agriculture.

Teaching in colonial America was concerned essentially with religion. Our first institution of higher learning, Harvard College, was founded to train preachers. As shown in figure 1, religious and private institutions dominated the educational scene until the Civil War. With expansion to the west following the revolutionary period, an increasing population, and an accelerated industrial tempo, the position of the farmer was favored—at

least temporarily. At that time an interest in agricultural education began to develop.

President Washington, in his annual message to congress in 1796, pleaded for a national board of agriculture which among other functions was to encourage experimentation and discovery. Proposals were also voiced at that time for the establishment of a national university. Interest in the improvement of agriculture had already begun in England and Europe. *The Society of Improvers in the Knowledge of Agriculture* was founded in 1723 by a group of Scottish farmers. That was followed by the establishment of the *Bath and West of England Society* in 1777, and the *Highland and Agricultural Society of Scotland* in 1784. In America, societies for the promotion of agriculture were founded at Philadelphia and in South Carolina in 1785, Maine in 1787, New York City in 1791, and Massachusetts in 1792.

The idea of the cattle show as a distinctive American institution was suggested by Elkanah Wilson of Albany, New York, in 1807, after he had exhibited two Merino sheep "under the great elm tree in the public square in Pittsfield, Massachusetts". Wilson was a business man engaged in the building of canals and stage routes (3).

Following the settlement of our difficulties with England in 1812, and the silencing of Napoleon in 1815, agricultural teaching began to receive attention with the initiation of agricultural experimentation. During the third decade of the nineteenth century, Justus von Liebig conducted scientific agricultural studies in Germany, and Jean B. G. D. Bousingault maintained a chemical laboratory on his farm in France where he carried on a combination of field experimentation and laboratory investigation. In England, also, John B. Lawes began experiments in 1837 with the use of superphosphate on his estate in Rothamstead. Of importance, too was the founding of the *Royal Agricultural Society* in 1838 (14–15).

In America the period 1819 to 1830 brought forth the evolution of manual-labor schools. Also Horace Mann, that great pioneer in the field of teacher training, was responsible for the initiating of teachers' institutes in 1837. Somewhat later between 1849 and 1854, movement began for the establishment of free public high and grade schools (6).

Heightened interest in agriculture was fostered in the United States when the Commission of Patents began the distribution of seeds and plants in 1839. Recognition of the importance of various phases of agriculture began to develop, for in 1855 the Patent Office undertook the study of injurious insects and employed a chemist and a botanist to work on agricultural problems. Organized agricultural research was initiated in the period from 1854 to 1858 by the Pennsylvania Agricultural High School, Michigan Agricultural College, and Maryland College (14).

Immediately prior to the Civil War period a considerable expansion into the midwest and Great Plains areas took place. There was a great

movement of the population to the more fertile lands beyond the Appalachians and 20 new states were created. Much activity took place in the building of roads, canals, railroads, and telegraph lines. Close on the heels of the gold seekers, stockmen took over the plains region. Descendents or followers of English and Scottish landholders, some adventurous aristocracy, and a sprinkling of Spanish dons constituted a class that was the most rugged of the "rugged individualists". The history of Great Plains agriculture depicted in the well-known stories of conflict between the cattle barons and the sheepmen, and the violent fate of homesteaders who dared place fences on the grasslands, reminds one of the feudal lords of old. Animal science teaching through the years has been greatly influenced by that heritage. It is difficult to find a department of animal husbandry that has been uneffected.

By the time this society was organized the pattern of agricultural teaching as we know it today was firmly established. The Morrill (1862–1890), Hatch (1887), and Adams (1906) Acts had all become statutes—not through the efforts of agriculturists or teachers—but by men of the commercial class who were supported more strongly by labor than by agriculture. The *United States Department of Agriculture* (1862) was an actuality. In the same year (1862) the passage of the Homestead Act intensified the expansion of agriculture to the west, and increased the need for training of agricultural personnel. The year 1867 saw the founding of the *National Grange of the Patrons of Husbandry* and the first meeting of the *Association of American Agricultural Colleges and Experiment Stations*. The latter organization was formally organized in 1889 and later (1919–1926) changed its name to the *Association of Land Grant Colleges and Universities*. The great power of that organization was impressed increasingly on higher learning, and in 1958 the record shows that some 60% of all college degrees were conferred by land grant institutions which comprise only some 3% of all degree granting institutions.

The first regularly organized agricultural experiment station was established at Wesleyan College, Middletown, Connecticut in 1875 under the directorship of Dr. Wilbur Olin Atwater. Following this the *Bureau of Animal Industry* was created in 1884 (3).

In 1899 the Association of American Agricultural Colleges and Experiment Stations considered a syllabus for a course in animal husbandry (zootechny) which was to be incorporated in the four year course in agriculture shown in table 1 (3).

Zootechny (animal husbandry) was defined as the theory and practise of the production of animals that are useful to man. Material dealing with the diseases of animals was excluded and relegated to the area of veterinary medicine. The animal was to be studied in a general way under anatomy, physiology, and management which included animal types, breeding, feeding, hygiene, and systems of management. Besides mammals the studies were to include fowl, fish, beneficial insects, frogs, oysters, snails, and other

TABLE 1. COLLEGE AGRICULTURE CURRICULUM AT THE TURN OF THE CENTURY

Freshman year		Sophomore year	
Subject	Hours	Subject	Hours
Physics	150	Agriculture	150
Chemistry	150	Zootechny	(60)
Geometry and Trigonometry	155	Agronomy	(90)
English	120	Meteorology	60
Modern Languages	180	Agricultural Chemistry	180
		Botany	120
		English	80
		Modern Languages	100
		Drawing	60
Total	755		750
Junior year		Senior year	
Subject	Hours	Subject	Hours
Agriculture	150	Agriculture	190
Zootechny	(100)	Dairy	(70)
Agronomy	(50)	Farm Machines	(60)
Geology	120	Rural Economics	(60)
Botany	60	Veterinary Medicine	180
Physiology	180	Horticulture and Forestry	180
Zoology	120	History and Political Economics	190
Psychology	60	Ethics	40
Modern Languages	60		
Total	750		780

animals. Usually, there was some instruction covering poultry, and in a few instances separate poultry departments were established.

In 1900 as in 1958 very great importance was attached to the judging of animals. Students were given much practise in judging which was promoted widely by competitive contests. Colleges built up herds and flocks of different breeds including purebred animals of excellent record. Many colleges undertook the preparation and showing of animals in competition with livestock producers at fairs and shows, notably the International Livestock Show at Chicago. Undoubtedly that activity was as important in 1900 as it is now in the recruitment of students. It is quite probable, however, that the practice created much less antagonism on the part of taxpaying livestock men in 1900 than is now experienced.

College administrators were apparently much more critical in 1900 than presently in regard to entrance qualifications of the students. It was necessary that the high school graduate have completed successfully the following courses (3):

Arithmetic, including the metric system
Algebra to quadratics
Plane geometry
One of the natural sciences
Physical geography
United States History

English grammar and composition—together with the English requirements of the New England Association of Colleges and Preparatory Schools
Ancient, general, or English history
One foreign language.

It must be understood that early teachers of animal husbandry were not trained in that curriculum. They were graduates of colleges and universities where indoctrination comprised the humanities and pure sciences. Many were undoubtedly very much interested in agriculture, but few, if any, had had the practical experience necessary to teach adequately in an applied field according to the intent of the Morrill Act. As an unfortunate result the colleges produced many analysts but few agricultural experts. This situation was presumably encouraged by the passage of the Hatch Act which placed emphasis on scientific method and analytical procedures. On the other hand, efforts in many instances to give more attention to practical economic applications resulted in unwise abstraction in the study of basic principles of the natural sciences.

The Stage in 1908

In 1908 there was peace. The century was young, and our nation, which was becoming rapidly an industrial giant, was straining against an already shrinking frontier with the boisterous vigor of a teen-age boy adjusting to society. An earlier Roosevelt had recently flexed our biceps for the world to view by means of a global tour of our new navy. The territories of Arizona and New Mexico were in the process of absorption into the union of states. Teaching, having been interrupted in its development by a series of conflicts needed to wean us finally from mother England, was confronted by the painful transition from a Cotton Mather personality to a more practical one imposed benevolently by Senator Morrill some 40 years before.

The international scene was serene. Great monarchies appeared secure and content in divine familial indulgence. Only the arrogance of Kaiser Wilhelm I was irritating enough to warrant front page mention in our newspapers. After all, the "silly" American experiment in democracy was confined by two great oceans and the French border. Even the United States was so preoccupied in building national wealth that little thought was given to the awesome consequences to come as humanity enslaved for centuries slowly recognized the equality of man, already thrice demonstrated in blood by two courageous republics.

At the first meeting of the American Society of Animal Production, it was probably unnecessary to conduct important discussion in the corridors of the convention hotel. Neither was the membership diverted by imposing series of committee meetings, invitational breakfasts, luncheons, and cocktail hours. Conversation was concerned most likely with the recent election of President Taft and the encouraging response of the stock market which earlier had suffered a rather sickening decline, referred to more recently

as the "Panic of 1907". Then, too, there was an announcement by J. Ogden Armour of scholarship awards to 20 student livestock judges to attend state universities and agricultural colleges (1). It is also quite certain that considerable debate occurred relative to the performance of Thomas Sinclair of Scotland as a judge following an announcement by B. H. Heide, superintendent of the International Livestock Show (1).

Any mention of celestial matters, during that first meeting, obviously would have been made only by a most foolhardy person in closest confidence, and would have been restricted to the anticipated return of Haley's

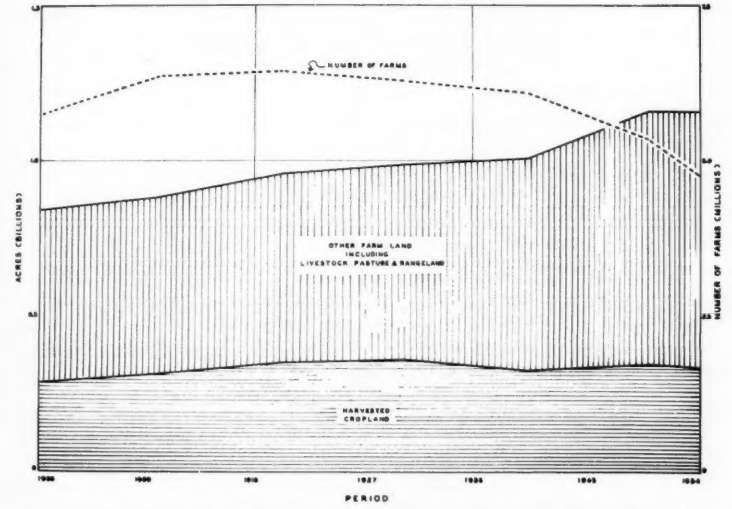

Figure 2. Change in Number of Farms and Distribution of Farmland: 1900–1954 (2, 6, 11, 14).

comet two years hence in 1910. One might quite safely assume that discussion relating to the teaching of animal husbandry would have had an equal opportunity along with competition for research grants on the convention program.

The frontier of agricultural expansion closed about 1890. Civil War and post war periods saw an over-investment of capital that ended in a series of panics. Agriculture, nevertheless, was entering an era of unparalleled prosperity which was enjoyed until 1914. In fact, from 1860 onward the United States became the chief source of food products and raw materials for Europe (5).

Although the population living on farms and ranches continued to increase until 1910 (figure 2), a new frontier was needed to appease the

appetite of a growing industrial giant. Population increase and its redistribution following the Civil War, coupled with the fact that there was no more new land to settle, forced each social class to examine its lot, and to consolidate and improve its position. Commerce was forced by labor and market to undertake a program of research, invention, and advertising which was to become collosal. Agriculture set about on a program of improvement in the quality of products and increased production. Land grant college administration began to concern itself with divisional and departmental organization, and also with the coordination and revision of curricula with which it remained occupied until post-World War II. Efforts were made mainly by departments of professional education to improve the training and quality of teachers. That move apparently did not receive very friendly reaction from those responsible for the development of the land grant colleges. Animal husbandry teachers placed major emphasis upon livestock judging and selection as a necessary step towards improvement.

It will be recalled that the Morrill Act provided for the teaching of manual arts as well as agriculture in the land grant colleges. When, in the beginning, his bill was adversely reported out of the Public Lands Committee, Senator Morrill pointed out that ". . . under the constitution a way had been found to protect and to promote commerce, to educate officers of the Army and Navy, to open up fields for internal trade by immense grants to railroads, to protect literary labor by copyright, and to encourage inventors by patents, but direct encouragement to agriculture had been withheld. . . . Miners and merchants should also have the means to acquire cultural skill and efficiency (3)".

Deficiencies in agricultural teaching and their causes have been explained. The shortcomings in the teaching of mechanic arts by the land grant colleges, however, were appreciably more serious. In our rapidly growing industrial society, there was a great need for the training of workers for all types of manufacture and commerce. The passage of the Morrill Act, in fact, was strongly supported by labor groups as well as by non-agricultural businessmen.

Prior to the turn of the century numerous manual training and state agricultural schools which did not receive support from land-grant measures were established. The rapid change in status from farm laborer to farm owner promoted by various land and homestead legislation directed attention to agricultural teaching of farmers on the farm and in the high school. Coupled with the popular thinking associated with these events there developed widespread interest in on-the-farm demonstration of experimentation that was pioneered principally by Seeman A. Knapp in the southern states which were effected most extensively by the Civil War. A direct consequence of these facts was the passage of the Smith-Lever Agricultural Extension Act in 1914, which combined with later measures such as the Clark-McNary Act of 1924 and the Capper-Ketcham Act of 1928

established, firmly and generously, the Agricultural Extension Service (14). Hence, teaching was given off-the-campus not only to the farmers and ranchers but also to their children in the 4-H clubs. To date, the 4-H clubs represent one of the most important stimuli for the support and advancement of agriculture in the United States.

Concurrent with this extension idea and of parallel importance was the development of manual training. Considerable national interest had been aroused earlier by Russia's exhibit of manual training at the Centennial Exposition in Philadelphia during 1876. It was realized gradually that teachers had to be prepared for training workers to fulfill many industrial needs. Mounting demands illustrated the necessity of this fact (3). In 1917, therefore, the passage of the Smith-Hughes Education Act and later in the decade of the thirties, the George-Dean Act supplied federal support to vocational and agricultural teaching in the high school system. The Future Farmers of America, a youth organization established in 1928, was an outcome of such demands and measures (14). By 1916 no less than 31 states required that an agricultural course be taught in their high schools. Twelve states demanded agricultural course work as a qualifying prerequisite for certificates of candidate teachers.

Crisis

From the time this society convened for its first meeting until 1916, the national expenditure for higher education had risen approximately 500% to a figure of $110,000,000. During the same period of time, college and university enrollment had more than doubled and numbered 329,000. Institutions not under state control, those which had been established principally for education in the liberal arts, yielded to public demand and began to add numerous professional curricula, such as: business administration, engineering, journalism, commerce, and finance. Opinion was becoming almost universal that a college education should be available to everybody and that everyone should have a college education. Land grant college administration intensified activity in curriculum reorganization. Animal husbandry departments cooperated by increasing judging, production, and economics courses at the expense of the physical and biological sciences and the humanities.

On April 6, 1917, the United States entered a war to protect democracy, and thereby introduced the world to the first global conflict. At the close of that war few crowned heads remained, their place being taken by nationalism, naziism, fascism, and communism. The tremendous wealth and productive power of the United States was demonstrated decisively; so well, in fact, that our per capita contribution to international parasitism had risen to approximately $1,400 per year by 1957.

All wars result in serious economic disruption. World War I did this, also, but on a global scale. The depression was felt, in all probability, most sharply in the United States where technology had been carried to its

maximum development. Technology was being experienced by society in many ways. The production of labor was increased and the pattern of life of the industrial worker was changed. The status of women in society was altered, and the birth rate changed drastically. Farm tenancy increased. The old line which separated government from economy was erased, and systems of taxation and local government became obsolete. Culture was unified. Economic power began to concentrate into the hands of fewer people in large corporations.

Prior to World War I farmers comprised approximately one-third of the total population and received about 17% of the national income. During the 1930's, about one fourth of the population were farmers who received approximately 9% of the national income. The position of the agriculturalist became correspondingly worse as price competition declined in industry and the labor market, and as capital and labor became successful in establishing a floor under prices and wages (5). Because of the tightening economic position of the farmer, certain legislation became necessary for his survival. Many measures were enacted—beginning as early as 1910—dealing with credit, loans, insect and disease control, commodity standards, marketing, tariffs, farm tenancy, and price stabilization. Legislation supporting Experiment Station research principally in the area of preparation, distribution, and marketing of agricultural commodities was embodied in the Purnell Act of 1925 and the Bankhead-Jones Act of 1935 (3, 14). This trend of conditions effecting the farmer was directly reflected in a downward trend, percentage-wise, in the enrollment of agricultural students in institutions of higher learning.

The growing spirit of democracy throughout the world, and particularly in the United States began to give the word "labor" more dignity and breadth of scope. In 1908 the total recorded vote in labor unions was 16,892, but in 1957 that had increased to 15,285,954 even when those unions having less than 25,000 members each were eliminated from the count. World War I, also, had induced a strong Americanization movement probably based to a great extent upon conscription illiteracy statistics. Churches, religious organizations, mens' and womens' clubs, labor unions, and labor colleges were collectively active in sponsoring a better education for greater numbers. In 1925–26, the Carnegie Corporation of New York invited conferences of leaders to study adult education and facilities. An outcome of these meetings was the formation of the American Association for Adult Education.

The war, post-war inflation, and depression years that followed firmly established the twentieth century as the beginning of the psychological epoch. Motivations began to change from those governed by moral law, reason, and humility to those encouraged by fear, distrust, ego-pampering, and frustration. Truth, respect, and frugality, became less virtuous than "belonging-to-and getting-along-with-the-group". Conditions had prepared

ideally a great mass of humanity for "brain-washing" and regimentation. Individuals with questionable preparation, and equipped only with a battery of "intelligence tests", entrance examinations, and digital computors set about on a program of human classification so magnificent in scope as to dwarf the Inquisition. Independent thinkers were given the label of non-conformist and introvert. The universal obligation became winning friends and influencing people with a permanent smile, window-dressing, and a pat-on-the-back. Dynamic leaders disappeared. In their stead arose static followers whose minds and purses have been mortgaged to eternity.

Hardly had the world recovered from the depression created by World War I, when in 1938 a famous discussion of "peace in our time" at Munich prepared humanity for World War II and a seemingly endless rash of "police actions" to follow. Institutions of higher learning at first contributed their staffs and student bodies to the military services, and then undertook many programs for the training of military personnel. Following the termination of major hostilities huge numbers of separated men and women—many of whom were married and had new families of various proportions—returned to college. Administrators were confronted with the tremendous housing and campus expansion to care for not only the returning enrollees, but also the products of war induced reproduction.

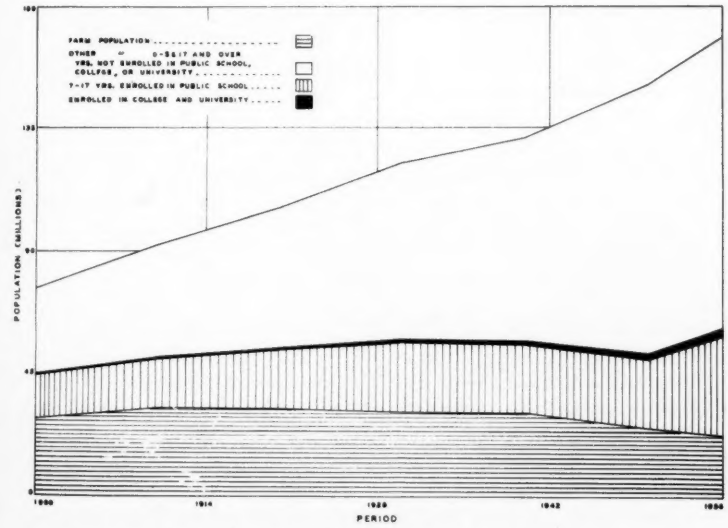

Figure 3. Enrollment in Educational Institutions Compared to the Total and Farm Population: 1900–1956 (2, 6, 11, 14).

Again the mounting desire of the rank and file citizenry for better and more widespread education (figure 3) was seen in the activities of groups such as the National Citizens Commission for the Public Schools, National Congress of Parents and Teachers, General Federation of Women's Clubs, National Association of Manufacturers, United States Chamber of Commerce, UNESCO, General Electric and other large corporations (8). Various laws were enacted, mainly by the 79th Congress, to assist returning veterans in obtaining an education. The Lanham Act provided support for temporary student and faculty housing combined with facilities other

TABLE 2. BACHELOR OF SCIENCE AND ARTS DEGREES GRANTED BY ALL DEGREE GRANTING INSTITUTIONS IN THE UNITED STATES (2, 11)

Year	1909	1958
Total B.S. and B.A. Degrees	25,209	287,401
Total in Agriculture	167	6,318
Total in Animal Husbandry	—	1,158
Percent in Agriculture	0.66	2.19
Percent in Animal Husbandry	—	0.40

than housing. Senator Fullbright initiated legislation that would support foreign study by means of the sale of excess public holdings abroad. The *Food and Agriculture Organization* was established in 1945; and in 1946, President Truman announced the appointment of a *National Commission on Higher Learning* (8, 14).

Taxation, production costs, labor problems, and population pressure were causing movement from a free to an administered economy in America. There was growth of corporate enterprise on all sides. That was true even in agriculture (5). The fact that by 1940 there were no less than 30 billion-dollar corporations bears witness to this. This relationship between industry and government was becoming rapidly the important political issue of the age—similar to the relationship of Church and State in the Middle Ages. The ownership of industry, furthermore, was shifting into the hands of women, who, as yet, have not shown inclination towards organization (13).

In this re-orientation of American life, certainly, agriculture is a fundamental issue. It is a matter, most assuredly, whose solution will require the attention of educational statesmanship of the highest order (8).

While it appears that agriculture and animal husbandry have held their own insofar as graduates are concerned (table 2), demands for changes in curricula have developed with dramatic suddenness, and threaten to change the picture rather drastically.

Shown in table 3 are the results on animal agriculture of the effects of replacement of the horse by mechanization, replacement of wool by synthetics, dietary changes, and food production for foreign countries.

TABLE 3. TRENDS IN LIVESTOCK NUMBERS. 1900–1957 (11)
(THOUSANDS)

Year	All cattle	Milk cows	All sheep	Hogs	Horses and mules
1900	59,739	16,544	48,105	31,055	20,995
1910	58,993	19,450	50,239	48,072	24,211
1920	70,400	21,455	40,743	60,159	25,742
1930	61,003	23,032	51,565	55,705	19,124
1940	68,309	24,940	46,266	61,165	14,478
1950	77,963	23,853	26,182	58,937	7,781
1957	95,166	23,028	26,370	52,207	3,558

To the above might be added such factors as the need for increased fertilization, declining water reserves, contract farming, and more recently the integration of agriculture into the business of manufacture.

The animal husbandry curriculum of 1908 was given previously in this paper. Changes in that curriculum which have occurred during the period of existence of the American Society of Animal Production were ably presented by Dr. Roy Kottman at the 1957 meeting in Chicago. In 1956 animal husbandry students were required to complete the following subject material (10).

Animal Husbandry	Credits	Other Agriculture	Credits	Other	Credits
Marketing, Types, Classes	3.63	Agronomy	11.13	Natural Science	14.72
Production, Management	9.50	Ag. Engineering	2.97	Physical Science	17.63
Feeds and Feeding	2.81	Dairy Industries	2.16	Social Science	8.25
Nutrition	2.94	Farm Management	5.28	Communications	10.13
Breeding	3.06	Veterinary Med.	4.97	Restricted Elect.	4.63
Meats	2.43	Other	5.76	Free Electives	18.42
Other	2.69			Other	14.94

A study of college and university catalogs for 1957 revealed that animal husbandry staffs are rather well prepared. In 45 departments reviewed there was a total of 448 professional staff members. The distribution according to academic degrees attained was as follows: Doctor of Philosophy 215, Master of Science 159, Bachelor of Science 67, and Doctor of Veterinary Medicine 7. That teaching has not received its share of benefit, however, from advanced preparation of staff, was pointed out in a study reported by Dr. C. S. Hobbs (9). A canvass of 26 animal husbandry departments showed that only 46% of staff time was devoted to teaching, and that those members having the Ph.D. degree did only 27% of the teaching. Furthermore, teaching ability was not listed among criteria considered in staff employment. A weight of only 9% was placed on experience, but a total of 43% was based on personality categories.

The student with which we have to deal today generally reflects the past 30 years of vocational education and progressive relaxation of standards in our high school system. He comes to us well indoctrinated in the

social values of imported sportscars, disrespect of experience and authority, and is motivated by the desire to "be one of the gang". It is very difficult for his advisors to interest him in basic natural science, mathematics, humanities, or communications, because he has learned to fear or hate these subjects. His desire mainly is to take livestock judging, animal production, and economics—the latter subject he has been informed will teach him how to make money. All of this is well documented by the fact that one-half of the freshmen enrolling in college animal husbandry have A.C.E. test scores below 50 percentile. Two-thirds of this group enter with scores below 60 percentile (10).

Striking evidence supporting the urgent need for immediate re-evaluation of the teaching program in animal husbandry is given in figure 4 which shows employment areas in relation to the total population and enrollment in the total educational system. Furthermore, studies by Dr. Kottman show a decline in employment in farm and ranch operation and management and extension service. Areas showing an increase in employment of animal husbandry graduates were meat packing, federal government service, graduate study, agricultural business, non-agricultural business, and other pursuits outside of the field of agriculture (10). Future employment in professional services with the United States Department of Agriculture was estimated and classified recently by Dr. B. T. Shaw (12). Recruitment needs for 600 professional workers during a six month period were broken

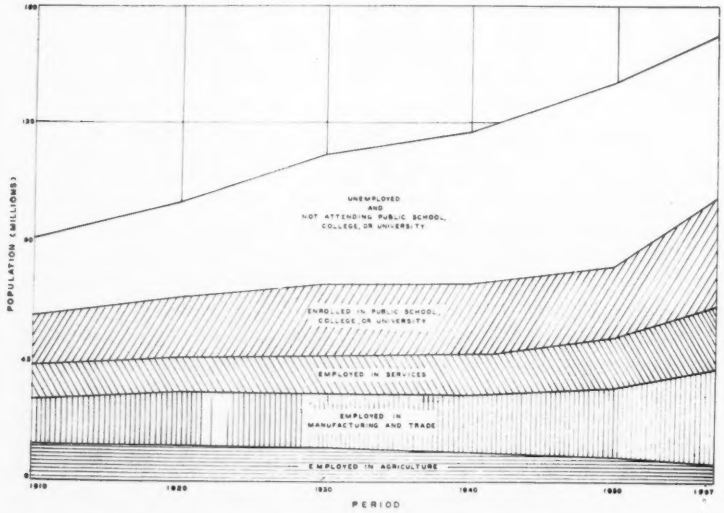

Figure 4. Classification of the Population with Respect to Employment and Educational Enrollment Categories: 1910–1957 (2, 6, 11, 14).

down as follows: Veterinary Medicine 150, Chemistry and Physics 141, Plant Pest Control and Inspection 85, Agricultural Chemical and Hydraulic Engineering 66, Agronomy 48, Soil Science 29, Agricultural Economics 27, Bacteriology 18, Animal Husbandry 15. In the animal husbandry group it is noteworthy that the needs were for geneticists and physiologists.

It has been intimated that the Russian contribution to the International Geophysical Year accomplished more "overnight" to impress the average American with science and teaching than all of our promotional programs. The press and other instruments of communication remind us almost hourly, by criticism or compliment, of our progress throughout the years, and prescribe various panaceas for the correction of our errors. The United States Office of Education announced on November 10, 1957, that Russian education was far in advance of that offered in this country and that our schools were not teaching sufficient mathematics and science. On November 13, 1957, President Eisenhower called for a "system of nation-wide testing of high school students, a system of incentives for high aptitude students to pursue scientific and professional studies, a program to stimulate good quality teachers of mathematics and science, provision of more laboratories and facilities and measures including fellowships to increase the output of qualified teachers". Congress has reacted by actions on numerous senate and house bills to assure the intellectual pre-eminence of the United States.

Figure 4 shows that our population is becoming markedly institutionalized when considered from the standpoint of enrollment in educational institutions and the military services. In connection with the rather considerable pending and impending military obligations faced by our youth, it would appear that some sort of a cooperative program between the military and colleges and universities would be collectively effective to education and defense (7).

Conclusion

The record of animal husbandry teaching during the past 50 years leaves much to be desired. Granted, there have passed across the stage of time a number of teachers whose service to humanity and agriculture establishes them for posterity as great "Greats". Teaching in general, however, has been treated as an orphan—being always considered secondary to research and other departmental activities. On the other hand, the teaching that has been done has not impressed youth with the value of organized past experience. The entirety of present society—parents and teachers alike—attempts to prolong the juvenile and dependent period of their life, yet our youth are old, very old. Discipline in any form whatsoever is becoming obsolete. Just what manner of pride can teachers feel when they are confronted with news reports of a mob of 2,000 students shouting insults and throwing stones and eggs at their president because of attempting tightening of rules pertaining to boy-girl parties at one of our foremost universi-

ties? Animal husbandry teaching in 1958 faces critical problems that cannot be solved by staff and committee actions motivated by the usual complacency of tenure and cooperative "back-scratching". Neither can they be corrected by the current contribution of from 10 to 20% of staff time to the relaxation and dilution of the "coffee-break" (per capita consumption: 1948—18.2 lb.; 1956—15.7 lb.). Energetic and realistic endeavor must soon be forthcoming if animal husbandry, yes, even agriculture is to meet the challenge now being presented to higher learning.

In the opinion of this writer the survival of animal science teaching depends entirely upon service to the public. Animal husbandry departments must correct, and quickly, traditional ideas of organization and curricula. In their stead must be initiated functional areas and procedures to meet public demands. Teachers must be selected, furthermore, on a competitive basis, alumni evaluation being given preference above that of freshmen or student campus organizations. Teachers must be permitted to teach rather than spend their time in endless committee meetings. Teacher's salaries should be comparable to those received by researchers, doctors, lawyers, and other professional people. Lastly, but not least, students must be disciplined and made to understand moral values. Teachers, in that respect, must be qualified and spontaneous in the examples they provide.

Are animal science teachers able and willing to accept the challenge?

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THE NEXT FIFTY YEARS OF ANIMAL SCIENCE

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RESEARCH is the foundation of all true and permanent progress, but research results hid in the "Ivory Towers" of a laboratory are of little value until they are applied to the basic problem of livestock production. The so-called arts of Animal Husbandry will gradually become the science of animal production. Science and technology will become an everyday part of the breeding, feeding and management of livestock on the farms, the ranches and feedlots of this nation in the next half century. Animal husbandmen will become animal scientists basically trained in the fields of animal breeding, genetics, nutrition, physiology, meats and production. More basic research will be done through collaboration or even employing men to work with livestock who are highly specialized in the fields of biophysics, bacteriology, chemistry, climatology, endocrinology, mathematical statistics, metabolism, pharmacy and medicine. More institutes and laboratories will be established for pure basic research free from the pressure for immediate application; this will lead to great discoveries for the livestock industry.

W. M. Beeson

In this paper I shall attempt to predict the direction we will take in the various segments of Animal Science in the next 50 years. Needless to say, many of these predictions may never come to pass because factors beyond control of man may alter this course. However, I hope this may serve as a stimulus to those engaged in teaching, research and extension in their respective fields in Animal Science. The advances made in the field of Animal Science in the next 50 years will be unparalleled in the history of the livestock industry. The only sure thing about predicting the future is that there will be a change in all phases of the livestock industry. For better or for worse, these changes will take place at an accelerated tempo.

Water

Water is one of the most important nutrients for man and animals and has always been taken for granted due to the fact that in most areas water is plentiful for drinking purposes and is not a limiting factor. However, in the future there will be more pressure on water supply; and, there-

fore, it will be important to have more definite information on the actual water requirements of livestock and its influence on metabolism.

Chemically pure water is H_2O, but water supplies contain varying amounts of mineral elements and other nutrients which have some influence on livestock production. In some areas water also carries toxic elements such as fluorine. In the past we have not recognized that probably a contributing factor in the variation between experimental results in different sections of the country has been due to the introduction of nutrients, particularly mineral elements, in the water supply. If we do more basic research to study the nutritional requirements of livestock, it will be necessary to use pure sources of water. As an example, in our research at Purdue University to study the manganese, magnesium and zinc requirements of swine, it was necessary to free the water from these elements in order to obtain critical data on the requirement.

Future research will have to take into consideration the relationship of water requirement to dry matter intake and the influence of water intake on the digestibility of nutrients. Water may become an important way of introducing nutrients into the diet both from the standpoint of furnishing essential elements as well as medication. It is well known that sick animals will drink water and refuse feed. This fact leads me to believe that water will become an important carrier for nutrients and medicants in the future, particularly in cases of animals that are afflicted with disease and subjected to stress conditions.

Energy

Over the past 50 years the standard for formulating rations for livestock has been based on Total Digestible Nutrients which have served well to estimate the requirements of animals in the past. However, TDN values were established during a period when our knowledge of nutrition was rather meager; and, therefore, the values given in the TDN tables do not necessarily apply to the type of feeding that is being practiced at the present time. New values for the energy content of feeds will have to be established in light of the many nutritional discoveries and feed additives that are used in livestock rations. In the future digestible energy and metabolizable energy will be the standards for feed evaluation because these techniques are a truer measure of the value of feedstuffs than Total Digestible Nutrients. The mere conversion of Total Digestible Nutrients to digestible energy introduces too much bias because the basic TDN values are not necessarily correct. Therefore, we must encourage all research workers to re-evaluate the energy value of feeds based on the present balance of nutrients and for each species involved. It is erroneous to believe that we can use the same energy values for feedstuffs for ruminants and monogastric animals.

Eventually, the energy value of all rations will be expressed on the basis of kilocalories.

Protein

Crude protein (nitrogen x 6.25) has been used as a standard for expressing the protein requirements for both ruminants and non-ruminants over the past 50 years. It is quite obvious that crude protein might be a fairly good measure of the protein requirements of ruminant animals where you have the synthesis of true protein and amino acids by bacterial action. Crude protein is a poor measure of the requirement for monogastric animals because the limiting factor in the protein requirement for swine and other monogastrics is the amino acid balance.

Protein requirements for swine will someday be expressed on the basis of amino acid requirements, and this will result in an actual lowering in the amount of protein that will have to be supplied for maximum growth. A few years ago it was recommended that weanling pigs should be fed a ration containing 20–22% protein. Research at Purdue has shown that if the ten essential amino acids are fed at the proper balance and level, a 30-lb. weanling pig will grow normally on 7.5% protein equivalent from amino acids and 3.9% protein equivalent from diammonium citrate. This ration had an equivalent of only 11.4% protein. These data show that the high level of protein required by pigs is due to its poor quality and that the limiting factors are certain essential amino acids.

In the next half century the protein needs of pigs will be thought of in terms of supplying the correct amount and proper balance of essential amino acids. Pig diets will be supplemented with pure amino acids. The ones which are probably the most limiting at the present in natural rations are tryptophan, methionine and lysine. Pigs can use a certain percentage of non-protein nitrogen to synthesize non-essential amino acids if the proper amounts and balance of essential amino acids are present in the diet.

Protein requirements for ruminant animals, such as sheep and cattle, must be reassessed because the early requirements were based on the crude protein source supplying other essential factors besides protein *per se*. The protein requirement for ruminants will gradually be lowered as we isolate and identify the nutrients that are essential for bacterial synthesis in the rumen.

Non-Protein Nitrogen. Each year larger amounts of urea and ammoniated products are being used as a source of nitrogen to supply part of the protein requirement for cattle and sheep. Most of the research to date has indicated that the rumen bacteria cannot synthesize effectively more than 1/3 of the daily protein requirement of the host animal. The limiting factors in the synthesis of protein by bacteria from nitrogen is a fertile field for research. Potentially, it is possible for a ruminant animal to synthesize all of the protein necessary from non-protein nitrogen sources, such as ammoniated products or urea, when we are able to determine the nutrients required by the microflora for maximum protein synthesis. Ammonia is released too rapidly from urea in the rumen for maximum use

by microorganisms. Basic research on rumen synthesis will eventually unfold the factors that are limiting in protein synthesis. So it is not too much to expect that in the next 50 years we will be able to supply the supplementary protein needs of ruminants from non-protein synthetic sources. Furnishing the protein requirement for milk secretion from urea is a different problem than for growth and meat production. It will probably be necessary to supply different nutrients for protein synthesis for milk production than we do for meat production.

As research progresses on these non-protein nitrogen compounds, we will gradually determine ways and means of slowing up the release of ammonia nitrogen in the rumen. Eventually these products will be coated with a substance that will cause a retarded release of the ammonia through bacterial action.

Carbohydrates

The abundance of carbohydrates in the U. S. A. from grain sources, such as corn, barley, wheat, oats, milo and many other grain products, has made us reluctant to study the adaptability of various carbohydrates to livestock feeding. Baby pig research has shown that early in life pigs require different types of carbohydrates for energy than they do later. We have found in our laboratory that early-weaned pigs placed on glucose as the only source of carbohydrate tend to scour, and they do not utilize the product very efficiently; but by the introduction of starch into the diet, we are able to prevent the scouring and improve the growth rate and well-being of the animals. It is well known that basically carbohydrates vary in their value for different species at different periods in their life cycle. As fundamental research increases, we will recognize that certain carbohydrates or mixtures of carbohydrates will be superior to others for a given period of time.

Roughages contain large amounts of crude fiber which is utilized most effectively by cattle, sheep and other ruminant animals. As far as we know, there are no enzymes secreted in the rumen that will tend to break down lignin; but we should recognize that there are enzymes that will break down lignin, and these could be introduced into the diet at the time of feeding or by enzyme action prior to feeding. Crude fiber is a potential but only partially tapped source of energy for ruminants, and probably some fiber can be utilized by monogastric animals such as swine. Brood sows during gestation will be fed on higher roughage diets, thus making greater use of corn silage, corn cobs, pelleted hay, etc. Rumen studies have shown that the utilization of fibrous materials is dependent on the proper nourishment of the billions of bacteria present in the paunch. As we discover the nutrients essential for maintaining and increasing the bacterial population, then we will be able to utilize more fiber in the fattening and growing rations of cattle and sheep and also for milk production.

Fat

Fat is an essential nutrient for life based on the presence of certain essential fatty acids such as linoleic, linolenic and arachidonic. Fat also serves as a valuable source of energy for livestock and has approximately 2.25 times more calorie value per unit than pure carbohydrates. The emphasis on decreasing the amount of fat in human diets and the partial loss of the soap market through the synthesis of detergents has released a large amount of animal fats for feeding livestock. Although this is a vicious cycle to produce excess fat on an animal, which is rather costly, and then feed it back to the animal, it still remains that livestock rations have served as an outlet for excess production of lard and tallow. Fat has been used mostly in poultry rations and now is being tested as a source of energy for swine. At present it is economical to feed animal grease as long as it does not exceed the price of corn by more than 2½ times. Fats have aided in improving the appearance and palatability of feeds, made pelleting easier, reduced the dust, curbed the wear on machinery and have increased the stability of vitamin A in stored feeds.

Although fats are playing a useful part in livestock rations, as the years progress and we produce leaner hogs, leaner beef and leaner lambs, the amount of excess fat will decrease rapidly. Except in certain high-energy rations, fat will tend to play a smaller part in the formulating of livestock feeds because grain products are usually a cheaper and more efficient source of energy.

Minerals

The importance of minerals, and especially trace minerals, has increased over the past few years and will continue to receive more recognition as we study the many interrelationships between the various mineral elements. Minerals not only need to be provided at the right level for each species at each stage of growth and development but also in the correct proportion to each other. Our knowledge on the trace mineral requirements of the various species of livestock is very fragmentary and more research is needed. Now that we are able to raise animals on semi-purified diets and pure sources of water, we will make rapid progress in determining the quantitative requirements for the essential elements.

A classical example of the effect of an imbalance of minerals on the requirement for trace elements is the production of swine parakeratosis through the feeding of excess amounts of calcium. This disease can be prevented by fortifying the diet with 50 ppm of zinc. Recently it has been established at Illinois and Purdue that zinc is required by swine regardless of the calcium level, but this condition is aggravated by feeding diets excessively loaded with calcium. Also, the research at Florida showing the interrelationship between copper and molybdenum is another example of the sensitive balance between certain elements.

There are over 100 elements in the periodic tables, and only 15 of these mineral elements have been classified as essential for animal life. Recent studies indicate that in certain species in a particular environment that molybdenum, bromine, fluorine and selenium have been identified as essential. The animal body contains 50 mineral elements, and probably these do not occur in the body by accident but many of them may have some essential function. By 2000 A.D. there will be many more mineral elements added to the essential list. The reason rare elements have not been identified as essential is because they have usually not been a limiting factor under practical livestock feeding conditions, and also our research techniques have not been refined sufficiently to detect their essential nature. Controlled environment, freedom from dust and air contamination, pure sources of redistilled water, purified diets and glass-lined pens will have to be used in order to study these new elements.

For many years we have assumed that most of the mineral elements that are present in natural feedstuffs are available to the animal. Of course, we recognize now that phytin is a poor source of phosphorus for animal life, and many other elements are bound in a form which are not available or at least only partially available. This also applies to rather crude sources of minerals such as different forms of phosphates because research has clearly shown that the phosphorus in soft phosphate with colloidal clay is not as available to swine, poultry and beef cattle as phosphorus from dicalcium phosphate. Phosphorus sources will be evaluated on the basis of availability to the animal rather than the basis of elemental phosphorus present.

Vitamins

The 20's and 30's were known as the "vitamin era", and during that time scientists characterized most of the fat soluble and water soluble vitamins that are used today in livestock feeds. Interest in the discovery of new vitamins was revived in 1948 when the combined efforts of many scientists isolated a red crystalline compound which would prevent pernicious anemia and was named vitamin B_{12}. As a result of this discovery, it was recognized that the main part of the animal protein factor, which was essential for chick and swine growth, was vitamin B_{12}. Since that time there have been no new vitamins isolated excepting the possibility of vitamin B_{13} which as yet has not been clearly defined and applied to livestock nutrition.

There is no doubt that there are many more vitamins of a distinct chemical nature which are being fed unknowingly to livestock each day. These are contained in the crude products that we use to formulate livestock rations but as yet have not been identified. In the last 50 years we have identified chemically 16 vitamins. The problem of isolating new vitamins becomes more difficult because they are required in fairly minute

amounts (micrograms) or even in parts per billion, which requires unusually refined techniques. With the renewed emphasis on basic research, there is a good possibility that we will discover as many new vitamins in the next 50 years as we have in the past 50.

It should be emphasized that many of the vitamins that are present in natural feedstuffs are not necessarily 100% available to animals. Corn has been known as a pellagra-producing diet, because of a deficiency of nicotinic acid (niacin). However, the biological assay of corn for niacin indicates that it contains sufficient amounts of this vitamin to protect pigs against this disease. Recently, research in England has shown that the niacin in corn is present in a form that is not entirely available to the pig unless it is hydrolyzed with alkali. Therefore, we are probably erroneous many times in assuming that assaying feeds for vitamins with microbiological tests measure the usefulness of the vitamins for large animals. Assay techniques will certainly re-evaluate the availability of the various vitamins in natural feedstuffs.

Rumen Factors

The mystery of the rumen has been steadily unfolding in the past decade through fundamental research studies at the various experiment stations. Huffman of Michigan and Burroughs of Iowa State, and more recently Bentley of Ohio, have made real and lasting contributions to determining some of the nutrients that are essential for stimulating rumen synthesis. Applications of these factors have been put to work in the feedlot by compounding supplements that contain the known nutrients that are essential for maintaining a high population of microorganisms in the rumen. These principles were applied to various poor roughages such as corn cobs, straw, etc.; and, as a result, a supplement was developed at Purdue University known as "Purdue Cattle Supplement A" which has been widely used by the feed industry and cattle feeders throughout the United States. Many modifications have been made of this supplement, but in general the same principles have been followed in formulation in order to obtain the maximum utilization of cattle feeds.

Many microbial stimulants are being discovered. Some of the more recent ones which have not been put into practice are products such as caproic, n-valeric, iso-valeric and iso-butyric fatty acids which assist in the digestion of cellulose. *In vitro* experiments have demonstrated that amino acids like proline and valine combined with either leucine or arginine stimulate growth of rumen bacteria. Unidentified growth factors for ruminant action have been shown to be present in dehydrated alfalfa meal, soybean oil meal, casein and many other crude protein products. Suffice it to say that we have only scratched the surface in determining the many nutrients that are required for maximum bacterial activity and digestion in the rumen.

Critical research on bacteria at the University of Wisconsin has shown that bacteria have genes strung along chromosomes just like higher forms of life. Some bacteria are males who can change the characteristics of females. Bacteria are a simple form of life, prolific, and a new generation is produced every 20 minutes.

Cattle feeding is thus becoming a science of bacterial nutrition as well as a science of cattle nutrition. The rumen story will unfold piece by piece, and eventually cattle rations will be as complicated and have as many nutrients supplied as swine and poultry diets. Basic rumen research will provide the answers to efficient cattle production in the next 50 years.

Enzymes

Studies have been conducted to determine the effect of certain enzymes on the utilization of feeds by various species of livestock. Enzyme research is still in its infancy; and although fundamental studies have indicated that certain proteolytic and amolytic enzymes might be helpful under stress feeding conditions, as yet the use of enzymes has not been of much practical value. Catron of Iowa State College has published data indicating that pigs under 3 weeks of age respond to the addition of pepsin in pre-starter rations. These data apply only to early-weaned pigs on diets that were made up with isolated soybean protein. Under practical feeding conditions, the use of pepsin in swine diets has not as yet been shown to be of any real advantage. Regardless of this fact, more research needs to be conducted on the use of various types of enzymes in livestock rations; and this opens up a new field for research which should be thoroughly investigated. There are many natural enzymes that occur in feedstuffs which may be of some value to the metabolism of the animal if they are properly activated. It is possible that some day we will be fortifying rations of young animals with certain enzymes which will aid in the digestion of feeds.

Feed Additives

Antibiotics. Antibiotics have become an integral part of most swine and poultry diets and are now being adapted to cattle and sheep rations. The broad spectrum antibiotics, chlortetracycline and oxytetracycline, originally increased the growth rate of swine 10 to 20% and improved feed efficiency about 5%. Continuous use of antibiotics with swine has gradually eliminated or reduced the growth-inhibiting microorganisms in hogs. As a result, the comparative response to feeding or not feeding antibiotics today is not as great as it was eight years ago. Antibiotics have not lost their effect. Actually, what has occurred is that the swine quarters have been cleaned up by the continuous use of antibiotics and thus the control pigs are receiving the benefit and gaining as rapidly as the antibiotic-fed pigs. If we discontinue feeding antibiotics, then we would revert back to the

same place we were in 1950. Most research workers are convinced that the degree of effectiveness of antibiotics is largely determined by the disease level.

Early research indicated that a mixture of broad and narrow spectrum antibiotics had no advantage over a single broad spectrum antibiotic. Recently this pattern has changed. Mixtures of chlortetracycline, penicillin, oxytetracycline and zinc bacitracin will improve gain and feed efficiency more than a single antibiotic. Apparently the type of harmful bacteria have been altered so that now the narrow spectrum antibiotics—penicillin and zinc bacitracin—are exerting a beneficial effect. This illustrates the changing pattern and evolution of microbial life. Within 20 to 25 years or less we will be feeding entirely different antibiotics to swine and other types of livestock than we are today. Antibiotics have been a great boon to the livestock industry; and if we continue searching for new and more effective antibiotics, then the use of antibiotics in livestock rations will last forever. If we become complacent and self-satisfied with the present tetracyclines, the penicillins and the zinc bacitracins, then slowly but surely they will be replaced with other types of bactericidal agents. Research workers must be bold in their effort to continuously screen new strains of antibiotics. The number of antibiotics available is unlimited.

Adaptation and use of antibiotics in ruminant diets has grown slowly but steadily. To date only two antibiotics have been found to be beneficial to improve gain, feed efficiency, carcass quality and health of cattle; namely, chlortetracycline and oxytetracyline. Only the keenest and most discriminating feeders are using antibiotics in their cattle rations today. Before the end of this century antibiotics will be almost universally used in cattle supplements to speed up growth rate, improve feed efficiency and carcass quality, and reduce disease level in cattle. Antibiotics will be discovered which are more specifically adapted to the needs of the ruminant. Eventually antibiotics will be isolated that will be more effective in specifically controlling shipping fever, bloat, scours, grubs, foot rot and different types of worms. Even now the tetracyclines are partially effective in curbing shipping fever and foot rot, and penicillin and oxytetracycline have shown promise in controlling certain types of bloat.

Laying on the shelf of some chemical laboratory is a compound or combinations of compounds that will prevent bloat. Research on bloat has been too superficial. When we learn the fundamental cause, we shall be able to provide the means of prevention.

Hormones. Hormone research is progressing very rapidly to control and alter the various life processes of man and animals. Diethylstilbestrol, called stilbestrol, (a hormone-like substance) is widely used in feed lots and in range cattle operations in this country. At present it is estimated that 70% of all beef cattle on feed are either fed or implanted with stilbestrol. With the exception of antibiotics, no feed additive has been more rapidly accepted and used than stilbestrol. Stilbestrol is fundamentally a growth

stimulant which increases gain about 16% and improves feed efficiency on the average of 12%. Stilbestrol does not improve carcass grade or quality or increase fat deposition. In lambs, stilbestrol has a similar effect on gain and feed efficiency but definitely depresses carcass grade and fat deposition. There is no benefit from feeding or implanting stilbestrol in swine.

Today stilbestrol is the best growth stimulant available for ruminant animals. Within a few years this picture will change, new hormones will be discovered. Recent studies at Colorado, Florida, Ohio and elsewhere suggest that a combination of oestrogenic (stilbestrol) and androgenic hormones (testosterone) may give better results than stilbestrol alone. Male hormones seem especially well adapted to heifers. Progesterone and estradiol combinations have given excellent results with cattle and lambs in the feedlot. Research at Purdue has indicated that certain chemical modifications of testosterone show promise in reducing the amount of fat and increasing lean meat in swine.

Thyroprotein has been tested extensively to determine its effect on growth and milk secretion in various species of farm animals. Under carefully controlled conditions with increased energy intake, feeding thyroprotein to lactating animals will increase milk production. However, animals vary in their natural secretion of thyroxine so the same level for all animals gives inconsistent results. Feeding thyroprotein to lactating sows has given conflicting data. Recent Iowa studies indicate that thyroprotein (iodinated casein) fed to sows at a level of 100 mg. per pound of total ration on a high-energy diet one or two days before farrowing and during lactation results in heavier pigs at weaning. Research at Illinois and unpublished data from other research laboratories have not found the feeding of thyroprotein beneficial. It appears that thyroprotein is not the answer to increasing milk production. New compounds will have to be tried.

Many goitrogens have been tested, such as thiouracil, propylthiouracil and thiourea, in an effort to improve performance and market quality in cattle, lambs and swine. Although it is possible to alter the appearance of the animal with these goitrogens, as yet the results have not been beneficial. Tapazole (1-methyl-2-mercaptoimidazole) is a very potent anti-thyroid agent and is used to treat hyper-thyroidism in humans. A progress report from Iowa indicated that feeding 200 to 600 mg. of tapazole daily to cattle would increase gain and feed efficiency above the effect of stilbestrol. To date other stations have not been able to obtain a stimulation from tapazole under their feeding conditions. At least this illustrates the determined interest in discovering new feed additives that will improve the feedlot performance of livestock.

Arsenicals. Arsenic compounds have been used for many years to cure certain diseases of man and as an insecticide. Arsanilic acid has been shown to improve gain and feed efficiency in swine when fed at a level of 90 gm. per ton of complete feed. Arsanilic acid is now being used as a feed additive in swine rations to improve performance, and also as a

treatment for certain types of diseases. Swine researchers at Iowa reported that 3-nitro-4-hydroxyphenylarsonic acid would decrease the backfat depth of market hogs 7 to 9%. It should be emphasized that these are preliminary tests, and more research needs to be conducted to determine the actual physiological action of 3-nitro-4-hydroxyphenylarsonic acid. Research at Purdue has revealed that arsenical compounds have no benefit in cattle rations. Arsenobenzene is being screened in several laboratories to determine its action on swine.

There are myriads of arsenic compounds that have not been tested for their activity in domestic animals. More than 35 arsenic-containing compounds are listed for medicinal use. Only a few of these have been subjected to crucial experiments with livestock. Arsenicals are relatively cheap bactericidal agents; thus, it is only logical to assume that their use will increase in livestock feeds. Persistent research will reveal new uses for arsenicals as medicants and as growth stimulants.

Tranquilizers. The impact of tranquilizers (ataraxic drugs) on the various segments of the livestock industry is still in the experimental stage. Since 1956 tranquilizers have been used by the medical profession to treat human patients suffering from different types of hyptertension and mental distress. Many times tranquilizers have been referred to as "happiness pills" or "don't-give-a-damn pills". These drugs have a definite physiological action on the animal organism bringing about a nerve-calming, pacifying effect and, if administered in large enough doses, complete sedation and sleep. Tranquilizers are widely used by the veterinary profession to quiet unfriendly dogs and calm wild and vicious animals.

More recently ataraxic drugs (tranquilizers) have been fed orally in small quantities to beef cattle, sheep and swine to study the effect of gain, feed efficiency, carcass quality and physical well being. Some response has been obtained by feeding hydroxyzine to cattle and sheep in combination with stilbestrol and oxytetracycline. Rauwolfia vomitoria and reserpine have given only a slight improvement in daily gain and feed efficiency in cattle. Reports on the use of tranquilizers in swine have been negative to date, but future research may reveal a positive effect.

A few tranquilizers which are now being tested with livestock are: phenothiazine derivatives such as chlorpromazine, perphenazine and promazine; Rauwolfia alkaloids such as reserpine and deserpidine; diphenylmethane derivatives such as hydroxyzine; and substituted propanediols like meprobamate. There are a large number of so-called tranquilizing drugs which are persistently being tested for their physiological action on mice, rabbits, cats and dogs.

The age of stimulants and tranquilizers is here and will continue to play a bigger role in animal and human behavior in the next half century. Here are a few possible uses for tranquilizers:

1. Reduction of shipping shrink and shipping fever in livestock.
2. Reduction in incidence of dark cutting beef due to excessive excitement.
3. Elimination of the shock of weaning calves, pigs and lambs.

4. Calming of wild animals for ease of handling.
5. Increase milk production in nervous sows and other lactating animals.
6. Reduction of livestock losses by stress factors.
7. Blocking "mother instinct" of animals.
8. Relieving tension and anxiety during certain operations such as dehorning, clipping, castrating, branding, etc.
9. Getting a ewe to adopt a lamb.
10. To pacify animals at parturition—especially farrowing sows.

Other Bactericidal Agents. Surfactants (detergents) have been reported as growth stimulators for poultry and swine. Most of the interest in surface active agents has subsided because the response from surfactants was not as great as obtained from antibiotics and arsenicals. In early tests (1952) at Michigan daily gain and feed efficiency were improved by incorporating Ethomid C-15 at a level of 0.1% in the diet of swine. Later (1953) investigations at Purdue showed no response from feeding Ethomid C-15, but a significant favorable effect on gain and feed efficiency was obtained by fortifying the diet of swine with 0.20% of alkyl benzene sulfonate. Trimethyl alkylammonium stearate fed at a level of 100 gm. per ton of feed gave a growth response intermediate between the controls and antibiotics. Interest has been revived in trimethyl alkylammonium stearate (tetra alkylammonium stearate) as a chemobiotic for cattle. Research results on this product are inconsistent and conflicting. Regardless of this fact, this type of research shows that a wide variety of products possess bactericidal properties.

Many other products such as furazolidone, streptomycin, and sulfaquinoxaline are now being tested in various combinations for swine. The chain of bactericidal agents is endless. At present we are in a state of flux and confusion, but basic and applied research will eventually set the pattern for the proper use of effective agents. The less desirable and less useful bactericides will be eliminated.

Evironmental Control

Animals today exist primarily under weather conditions that are peculiar to the climate of the area. Basic research at California, Purdue, Iowa and many other experiment stations has shown that animals are more efficient in their production if the environment is controlled to ideal temperature and humidity. Poultry are being produced now under controlled environment and, in a few cases, swine. Eventually swine will be raised entirely on concrete under a controlled environmental condition in air-conditioned hog houses during times of the year when the climate is not favorable. Controlling the environment of beef cattle and sheep will be a more difficult task; but under large feedlot conditions where the climate is not ideal, equipment will be provided whereby the temperature can be adjusted for maximum production. Just as man is gradually moving into controlled environment, so will animals.

Automation

Hand-feeding of livestock is rapidly becoming a thing of the past, and all types of animals—beef cattle, swine, sheep and dairy cattle—will be fed by push-button operations. The poultry industry has led the way in automation and now is far ahead of other classes of livestock in this field. The day of using the shovel and pitchfork as a means of handling feed on the farm will be replaced by power machinery, automatic feeders and unloaders, feed mixers and various other mechanical devises which will reduce the daily chore of feeding animals. Self-feeding will become the usual practice with cattle, sheep and swine instead of hand-feeding. Rations will be bulked up with roughages to control the intake of energy, various other ingredients, and to curb the appetite when animals are on limited feed. As we learn more about the nutrition of animals, it is quite obvious that we will be able to start cattle and sheep on full-feed the first day without gradually raising them up to prevent digestive disorders. In fact, this has already been done for several years under a research environment at Purdue University with both cattle and sheep. Digestve disorders and going off-feed are essentially a lack of a balanced diet rather than an excess of food intake.

Electronic-operated automatic weighing scales will be devised whereby weights can be recorded and animals can be weighed periodically without too much hand labor.

Definite improvements have already been made in automatic watering devices that do not freeze, and these will be more widely used under feedlot operations.

Pelleting

A large percentage of manufactured supplements are fed to livestock in a pelleted form. Pelleting is gaining in popularity because it furnishes feed in a condensed form which is easy to handle and prevents wastage. The final answer to the future of the pelleting of feeds will depend on the influence this mechanical process has on the nutritional value of feedstuffs. Research by Webb and co-workers at the Dixon Springs Experiment Station in Illinois has rather dramatically shown that the pelleting of poor grade hays will increase the consumption by ruminants, improve daily gain and feed efficiency. Pelleting high-energy diets for cattle has shown no advantage excepting, in some cases, a slight improvement in feed conversion. Although the fundamental reason is not known, it appears that diets high in fiber are more adapted to pelleting than those high in energy. Beneficial effects have consistently resulted from pelleting barley and oats for swine and, in some cases, even from the pelleting of high-corn diets.

Pelleting has a bright future in the feeding of farm animals because it has many advantages which will become more attractive in the years to come. Pelleting reduces bulk, prevents dustiness, permits self-feeding, is

well adapted to automation, eliminates sorting, permits the simultaneous feeding of nutrients and cuts down on digestive disorders.

Lamb research at Purdue has shown that pelleting a complete ration will more than double the daily gain and improve the feed efficiency about 34% as compared to hand-feeding of shelled corn, a protein supplement and hay.

Pelleting will eventually become an engineering problem; and as fast as we can develop machinery so that pelleting can be done economically under farm and feedlot conditions, then it will be adapted rather rapidly to many livestock feeding operations.

Harvesting and Preserving Feeds

Mechanization on farms caused by the shortage of manpower has brought about revolutionary changes in the harvesting and preserving of feeds for livestock. Eventually we will harvest and immediately store or preserve the feeds in the form that they are to be fed to livestock and eliminate many of the in-between processes and numerous chores of handling the feed as it is done today. The best example is the picking of high-moisture corn and directly shelling it or grinding it into a sealed, oxygen-tight structure which will preserve the feed in a form that is high in nutritive value. Research at Purdue and Iowa has shown that the ensiling of high-moisture ground ear corn (30–32%) for cattle will improve its feed value about 10% on a dry matter equivalent basis as compared to low-moisture ground ear corn that is cribbed. Storing high-moisture shelled corn for swine results in an 8% reduction in feed value for swine. In the next half century machinery will be developed whereby we can harvest the corn crop and process it immediately in the field and store it in structures ready for feeding. No longer will we go through the process of picking, cribbing, shelling and grinding corn before it is fed to animals.

Haymaking by the baling process will gradually pass out of the picture, and we will have machinery which will dry and pellet hay in the field ready for feeding. Ensiling crops, such as corn, sorghums and small grains, will increase because by this method we can more nearly preserve the nutritive value of the entire plant and increase the yield of product per acre.

New methods will be developed whereby feeds can be stored in structures that will preserve their original food value without deterioration. We have made some progress in this direction in using glass-lined silos and gas storage, but other methods will be devised to even improve on our present facilities.

Animal Breeding

Considerable progress has been made in the breeding and selection of livestock over the past half century, but this has been rather slow and tediuos; and our objectives in many cases have not been too well defined.

The pedigree and the appearance of the animal on foot has not always been correlated with the productive functions for which these animals exist. Therefore, in the future it appears that production testing of beef cattle, sheep and swine will grow very rapidly; and eventually in order to sell a breeding male at a top price, it will be necessary to have production records on his capacity to produce offspring that gain rapidly and efficiently, and have proper carcass value.

The purebred industry will be based primarily on the productive capacity of their animals rather than pedigree or show ring records.

Research is leading the way to the control of sex in animals. Techniques will be developed whereby it will be possible to control the sex of animals so that a breeder can make his choice as to the number of males and females that he desires to reproduce from any species of farm animals.

Time of mating and conception will be governed by the use of hormones so that each animal can be bred on the day desired instead of waiting for the natural occurrence of the estrual cycle. Hormones will be available for injection into pregnant females during the latter stages of gestation so that a group of sows, a flock of lambs or herd of cows will deliver their young on a specified day. Control of breeding and parturition will give a more uniform age and weight of animals at market time. Also, it will relieve the herdsman from waiting until a sow, ewe or cow has its newborn by natural term. This will allow more careful attention and good management during the critical period of parturition. It will not be uncommon in one herd for 50 or 100 sows to farrow in a short span of a few days, or 1000 ewes to lamb in one to two weeks, or 500 cows to calve in 14 days.

Artificial insemination has already been widely adapted in the dairy industry, and gradually the same idea will be used universally by the breeders of beef cattle, sheep and swine. This will allow a wider dissemination of germ plasm of the type that is most desirable for beef, sheep and swine production. Also, it will be possible to preserve semen under storage for many years so that future generations can make use of sires that have been proven to be productive and useful.

Meat

Meat producers and processors are recognizing that the public is demanding meat that is tender and palatable with a minimum amount of fat. The swine industry is facing a critical period in which it is being forced by public preference to produce a leaner type hog with less fat and a maximum amount of lean in pork chops, hams, shoulders and other cuts. This is being done by the production testing of hogs at various swine evaluation stations throughout the country to select breeding stock that will produce a large loin eye and a maximum amount of valuable cuts.

Scientists in Denmark have far surpassed us in the breeding and selection of meat-type hogs on the basis of carcass quality, rate of gain and

productive efficiency. For many years they have concentrated on selecting those animals for breeding purposes that produce hams and bacon that were acceptable for export market. Lard has become a "drug on the market" and no longer do we need excessive amounts of fat on hogs. Swine production in the future will be guided primarily by the right type of carcass with a maximum of lean pork from animals that will produce at least 1 lb. of pork from 3 lb. of feed or less and that have high productive capacities from the standpoint of milk secretion and heavy weaning weights of pigs.

Although the beef market is paying a premium for a certain percentage of fat in order to improve the palatability and tenderness of meat, in the years to come the amount of fat desired on beef cattle will decrease. Except for specialized markets, the prime steer will be a thing of the past. Through the use of tenderizing enzymes and other substances, it will be possible to take beef even from animals that are not fat and make them into tasty, palatable steaks and roasts. Fifty years from now, and maybe sooner, most of the quality of meat will be produced in the meat packing plants by processing rather than in the feed lots. Gradually we will devise rations to produce more lean meat and growth with less emphasis on the degree of fatness.

The sheep industry has gradually shifted from the dual purpose of lamb and wool production to a one-way road of lamb production for meat. Although wool is still a wonderful product from the standpoint of the manufacturing of clothes, there are many substitutes for wool—such as dacron, orlon, nylon and others—which are being blended with wool products and, in many cases, replacing wool. As yet a synthetic product has not been produced which is equal to wool in its weaving and wearing qualities; but as chemists continue to work in the laboratory on the synthesis of new fibers, eventually someone will produce a fiber equal to wool from the standpoint of the garment industry. Therefore, if the sheep industry is to thrive and flourish in the United States, it must emphasize the meat aspects rather than the wool. Lamb consumption could be increased in the United States by more emphasis on the proper quality of lamb and cuts that are palatable and contain a minimum amount of fat. We need a larger eye of loin in the lamb chop.

Internal and External Parasites

One of the great hazards and losses in the raising of livestock today is the occurrence of internal and external parasites. Grubs in cattle and worms in cattle, sheep and hogs, as well as lice and mange, cause terrific losses and reduce the efficiency of animals in converting feed into meat, milk and wool.

The discovery of Hygromycin, an antibiotic, to control the roundworms and other internal parasites of swine is a step in the right direction in gradually eliminating these parasites from the livestock population. Al-

though this is not the final answer, it furnishes a stimulation for research workers to search for other substances which will have equal or even superior effects. Phenothiazine has served well in assisting in controlling the stomach worms of sheep and cattle and piperazine for roundworms in swine, but as yet this is not the answer to the elimination of this problem. Eventually parasitologists will find anthelmintics which will break the life cycle of the various internal parasites and gradually eliminate them as a depressing factor on the health and well-being of livestock on the farm.

Trolene for cattle grub control was first announced by the U. S. Department of Agriculture and by the Dow Chemical Company in the spring of 1956. This product has been tested widely and shows promise to reduce the occurrence of grubs in cattle. This new drug is only one among many drugs that are now being tested to destroy the migration of the grub through the hides of cattle.

In a few years we should have numerous products which can be used to break the life cycle of all internal parasites and eliminate these pests from livestock.

Ticks, flies and other insects are annoying to animals and detract from their ability to convert feed into meat. The use of benzene hexachloride and other treatments have aided in reducing these pests. New products will soon be available for more effective control and elimination of flies and ticks.

New Sources of Nutrients and Energy

Many new sources of nutrients which are either not known or used today will become available for the production of livestock. Some of the more obvious and potential sources of nutrients and energy are as follows:

1. Sea and ocean water will be used as a source of mineral elements and water.
2. Algae may furnish protein and other essential nutritional factors.
3. Molds will be used as a source of estrogenic substances as well as feed nutrients.
4. Microbial and bacterial life will be employed as synthesizing agents for protein, vitamins and unidentified growth factors.
5. Sun will become a source of energy for controlling environmental temperature and factory synthesis of food products.
6. Atomic energy will be adapted to produce power for farm and livestock operations.
7. New crops and plant varieties which are not known or used today will be used as livestock feeds. Many of our present farm grain and forage crops will be replaced.

ABSTRACTS OF PAPERS FOR PRESENTATION AT THE FIFTIETH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meeting will be held November 28 and 29 at the Hotel Sherman, Chicago. The abstracts include program papers for the research sections and papers to be "read by title".

1. CARCASS QUALITY IN SWINE AS EVALUATED BY LIVE ANIMAL MEASUREMENTS. Stanley P. Wilson, C. D. Squiers and W. M. Warren, *Alabama Agricultural Experiment Station.*

The relationships between certain live animal measurements and carcass quality in swine were studied. The sample used consisted of 112 Landrace X Hampshire barrows, all grading U. S. No. 1. Shape and width measurements were taken at the shoulder, the last rib and over the top of the ham by pressing a section of soldering wire over these areas, carefully removing it and tracing the impressions on graph paper. Each animal was probed for thickness of backfat at these locations and carcass data were obtained. Live animal width values were significantly correlated with live probe, indicating that width was partially a function of backfat thickness. Shoulder, loin, ham and average widths were negatively correlated with percentage of lean cuts when weight was held constant; but when both weight and live probe were held constant, width was positively correlated with percentage of lean cuts. However, only the correlations for loin ($r=0.215$) and average width ($r=0.253$) were significant. Weight was negatively correlated with percentage of lean cuts ($r=-.313$) ($b=0.07$). In these data there was no correlation between yield of lean cuts and shape of animal as measured by relative widths at shoulder, loin and ham. Neither was there an association between shape of back and yield of lean cuts.

2. AN ANALYSIS OF SWINE BREED DIFFERENCES IN SIZE AND SHAPE OF LOIN EYE. Sofia Osinska, Ralph M. Durham, L. N. Hazel, *Iowa State College.*

Variation in eye muscle shape was studied on carcasses of 179 barrows from six swine breeds in two seasons. The barrows were from the Iowa Swine Testing Station and tracings were taken at the packing house. Shape index is the ratio of length of eye muscle to depth of eye muscle. Indexes varied from 1.38 to 2.73, the smaller index being an indication of a plump eye muscle, the larger being a flat one. Analysis of variance indicated significant breed differences in this index. The correlation between index and area was 0.40 indicating that plump eye muscles are larger than flat ones. A subjective scoring method for classifying eye muscle shapes was developed and an analysis was made of breed differences in shape. Each tracing was classified into one of five shapes by three different classifiers working independently. Breed differences were observed in deviations from expected, assuming *a priori* equal distribution of shapes within each breed.

3. THE INFLUENCE OF SIRE UPON SOME CARCASS CHARACTERISTICS OF ANGUS STEERS AND HEIFERS. Nat M. Kieffer, R. L. Hendrickson, Doyle Chambers and D. F. Stephens. *Oklahoma State University.*

Carcass data were available on 60 Angus steers and heifers produced by 7 different sires with 6 to 14 animals per sire group. The average age at the end of a 159-day feeding period was 386 days. The average slaughter weight was 886 lb. with a range of 815 to 938 lb. among sire groups. The average yields of loin, rib, round, and chuck were 17.60, 9.41, 22.08, and 28.33%, respectively. The ranges in percent yield among sire groups were: Loin, 17.36–17.96; rib, 9.14–9.73; round, 21.51–22.97; and chuck, 27.68–28.93. Sire differences for fat and lean percentage of the 9–10–11 ribs were small and non-significant. Heritability of tenderness as measured by the mechanical shear force technique and computed by the paternal half-sib correlation method was estimated to be 0.92 with a 95% confidence interval of approximately 0.40 to 1.44. Heritability of rib eye area unadjusted for differences in carcass weight was 0.56 with a 95% confidence interval of approximately 0.04 to 1.08. The correlation between rib eye area and carcass weight was 0.52. Significant sire differences were found for carcass grade, slaughter grade, marbling score, and percent bone of the 9–10–11 ribs. Intra-sire phenotypic correlations of marbling score with tenderness (−.08), with depth of fat over rib eye (+.22), and with rate of gain on test (−.08) were computed.

4. SOME GENETIC ASPECTS OF TENDERNESS IN BEEF. R. H. Alsmeyer, A. Z. Palmer, M. Koger and W. G. Kirk, *Florida Agricultural Experiment Station.*

The tenderness of broiled short loin steaks from 190 carcasses varying in grade and maturity was evaluated by a tenderness panel and Warner-Bratzler shear technique over a 2-year period. Cattle were Brahman, Shorthorn and various crosses that were sired by seven Brahman, six Shorthorn and two crossbred sires. Steaks from progeny of Shorthorn sires were on the average more tender than steaks from offspring of Brahman and crossbred sires. Differences in tenderness due to breed of sire were highly significant. Based on a 6-point scale, with the higher numbers being the more tender, scores were 3.5, 3.0 and 4.2 for Brahman, crossbred and Shorthorn sires, respectively. The heritability of tenderness was estimated from the intraclass correlation of offspring by sires of the same breed. The estimate derived from Brahman sires was 51% and zero% from Shorthorn and from crossbred sires. If breed of sire was ignored, the estimate of heritability was 129%.

5. GENETIC CORRELATIONS BETWEEN GROWTH RATE AND EFFICIENCY OF FEED UTILIZATION IN SWINE. D. Reimer, R. E. Comstock, W. E. Rempel and A. B. Salmela, *University of Minnesota.*

Genetic correlations between growth rate and feed cost per 100 lb. gain were estimated from paternal half-sib analyses in several inbred lines of swine in the Minnesota Swine Breeding Project. The data included 1080 litters from 391 sire groups in the Minnesota 1 (18 years), Minnesota 2 (15 years), and four Poland China lines (average 10 years per line). The genetic relationships estimated were: −0.61 (Minn. 1 and 2 pooled), −0.51 (Poland Chinas), and −0.53 (all data pooled), indicating that increased selection pressures on growth rate can be expected to bring about a corresponding response in the improvement of feed efficiency. Estimates of additive genetic variance quoting growth rate first, were: 0.0108 and 188.84 (Minn. 1), 0.0220 and 153.60 (Minn. 2), and 0.0208 and 27.36 (Poland Chinas); estimates of total phenotypic variance: 0.0551 and 941.80 (Minn. 1), 0.0527 and 1112.15 (Minn. 2), and 0.0589 and 793.16 (Poland Chinas). Hypothetical populations with selection programs designed to capitalize on the favorable genetic correlation between these two traits and their heritabilities are considered. A population similar to the Minn. 1

(in level of in-breeding, variability, and general management), and where about 6% of the available boars and one-third of the available gilts are retained for breeding purposes, suggests that individual selection for growth rate producing 0.1 lb. increase in daily gain may be expected simultaneously to improve feed efficiency by 6.5 lb.; however, litter selection for feed efficiency producing an 8.5 lb. reduction in feed costs may be expected to increase daily gain by only 0.06 lb.

6. BIOMETRICAL ASPECTS OF FEED CONSUMPTION, GAIN AND DAYS ON TEST IN SWINE. R. Willham, L. N. HAZEL, and R. Durham, *Iowa State College.*

The Iowa Swine Testing Station records for the spring and fall 1957 sire groups were studied. Each group consisted of one barrow and three boars fed together. The unit of statistical analysis was the group. Pens averaged 60 lb. per pig at the beginning and were taken off test when they averaged 200 lb. Total feed consumed, gain and pig days were analyzed for the first 35 days and for the complete test. This gives a comparison between a day constant and a gain constant test. Ratios of feed efficiency, average daily gain and average feed consumption were calculated from the pen totals. Because these ratios are not linear functions of the observations, they were transformed to a logarithmic scale. The correlations between these ratios were partitioned into the variances and covariances of total gain, days and feed. Within breed and season, the correlation between daily feed and daily gain was +.9 for both total test and 35-day test. The correlation between daily feed and efficiency was insignificant for both tests. The correlation between daily gain and efficiency was —.6 for the total test and —.5 for the 35-day test. Although the correlations were similar for both tests the predominant component of total test was the correlation of total feed with total days (+.5) while the predominant component for the 35-day test was the correlation of total feed with total gain (+.9). In the figures for the total period, season differences were found in total feed consumed, in daily feed and in feed efficiency.

7. THE INFLUENCE OF CARCASS GRADE AND FATNESS OF YEARLING STEERS ON CONSUMER PREFERENCE. J. F. Kidwell, J. M. Harper, J. E. Hunter, P. R. Ternan, C. E. Shelby and R. T. Clark, *University of Nevada.*

The 8th rib was obtained from the right side of each of 49 yearling steers for consumer preference studies. Each steak was broiled to an internal temperature of 60° C. A panel of four men and three women scored a sample of each steak for tenderness, flavor of muscle, flavor of fat, quantity of juice and quality of juice. A judge x carcass grade interaction was observed for quantity of juice. One judge consistently scored lower than the others for the remaining traits. There were no differences among the remaining judges and no differences due to grade. A correlation analysis indicated no association between tenderness score and fatness, average daily gain or any of the other preference measures. Flavor of muscle was associated with percent fat, average daily gain and quality of juice. The data indicate quality of juice is more dependent upon muscle constituents than on fatness. The data are too meager to warrant generalization, but clearly suggest the need for further study.

8. THE EFFECTIVENESS OF SELECTION FOR TYPE BY SCORECARD IN A SMALL HERD OF ABERDEEN ANGUS CATTLE. Elmer Krehbiel, C. J. Brown, Warren Gifford, Charles Mabry, *University of Arkansas.*

The annual records of evaluation of type by scorecard in a small purebred Aberdeen Angus herd consisting of 9 herd sires, 40 foundation females and 175 female offspring produced between 1941 and 1957 were studied to determine the effectiveness of selection for type. The average type score of at least three judges working independently each year was used to evaluate type. Twenty-five different

judges have appraised the cattle during the 16-year period. Repeatability was estimated to be 0.36 for contemporary cows and 0.42 for non-contemporary cows. Selection differential for females was calculated on the basis of current score, average lifetime score and most probable score. These values are mostly positive and indicate that selection was for improvement in type among females at the rate of approximately one third of a grade per year. Estimates of heritability were 0.33 from regression of offspring on mid-parent, 0.77 for intra-sire regression of offspring on dam and 0.24 for regression of offspring on sire. A paternal half sib estimate of heritability obtained from analysis of variance was 0.54. The annual mean scores of all females in the herd show an improvement of more than a grade in type with only a slight reduction in total variability of scores during the 16-year period. These data indicate that selecting for type on the basis of a scorecard was effective in improving the type of a small herd of purebred Aberdeen Angus. They offer a basis to predict the rate with which a small breeder may expect to change the type of his cow herd from selection by scorecard where bulls are purchased and replacements are raised.

9. RELATIVE FREQUENCY OF ABNORMALITIES OCCURRING IN CATTLE. Eldon Brum, N. S. Fechheimer and L. O. Gilmore, *Ohio Agricultural Experiment Station.*

Information on 601 abnormalities affecting 337 cattle was collected in cooperation with the Central Ohio Breeding Association, NOBA, Inc., and the Ohio P.D.C.A. The data were analyzed statistically to ascertain if the occurrence of animals, abnormal in any regard, or of particular types of abnormalities, was associated with various influences that would be characterized primarily as environmental or inherited. By the chi-square test of independence, it was shown that general environment, as measured by gross income per cow (census data) and month of conception was associated with the frequency of the occurrence of animals that were abnormal in some way. There was a lower than expected frequency of abnormal animals born within the presumed better environmental conditions. Animals conceived during the winter months were abnormal in greater frequencies than expected. Inherited influences, as indicated by breed differences, were shown to be associated with particular types of abnormalities as well as animals possessing abnormalities regardless of type. Both sex and sire differences indicated inherited influences but it was not shown that these differences applied to types of abnormalities, although these differences were significant with respect to the overall frequency with which abnormal animals occurred.

10. GENETIC ANALYSIS OF THE B, F-V AND Z BLOOD-GROUP LOCI IN AN INBRED JERSEY HERD. R. C. Laben and Clyde Stormont, *University of California.*

Blood groups of 270 cattle from the University inbred Jersey herd were classified as heterozygous or homozygous for alleles at the loci B, F-V and Z. The proportion of heterozygotes divided by one minus the inbreeding coefficient for inbreeding ranging from 0.00 to 0.56 was determined. The ratio rose slightly for each loci as inbreeding increased, indicating some excess of heterozygotes among the inbred animals. However, analysis within sires, where mate's genotypes were known, failed to indicate preferential survival of heterozygous calves. Milk yield (FCM) declined with inbreeding, but within sire groups of similar inbreeding, there was no consistent trend in differences among cows homozygous at none, to all three of the loci. Eleven B alleles segregated in these cattle. In one line, three sires, homozygous for the same B allele were used in succession. Within one of these sire-groups, 12 daughters heterozygous for that particular B allele yielded significantly more FCM than 9 homozygous daughters of similar inbreeding. A significant difference in reproductive efficiency, favoring the heterozygote, was found in a like comparison of 9 vs. 10 daughters

of another group. No other important differences were noted between heterozygotes and homozygotes regarding birth weight, FCM yield, reproductive efficiency, and disposal age. In summary, a slight excess of heterozygotes at three loci was noted; however, preferential survival of heterozygous calves was not demonstrated. In two instances, of limited numbers, cows heterozygous at the B locus outperformed their homozygous paternal half-sisters of similar inbreeding.

11. EVALUATION OF THE X-RAY METHOD OF DETECTING ANIMALS HETEROZYGOUS FOR SNORTER DWARFISM. Joe W. High, Jr., H. J. Smith, C. S. Hobbs and C. M. Kincaid, *University of Tennessee.*

For the past 4 years the X-ray method of detecting animals heterozygous for "Snorter" dwarfism has been investigated. This method is based on vertebrae abnormalities as shown on radiographs of young calves. This study includes the radiographs of some 1500 calves representing several different lines of breeding in both Hereford and Angus breeds. Also, included in this study are the test mating results of 89 animals (80 heifers, 9 bulls) X-rayed as calves. The data presented indicate: (1) There is considerable overlap within the range of normal to mild vertebrae abnormality between presumed non-carrier and carrier animals. Therefore, on the basis of these data the X-ray method is not a highly accurate method for identification of individual animals with respect to genotype for dwarfism. (2) The X-ray method is highly accurate in identifying "Snorter" dwarf calves. (3) Radiographs of a bull's progeny may be used as a general means of screening him for dwarfism provided some history of the dwarfism status of the cows mated to him is known.

12. PHYSIO-CHEMICAL AND MICROBIOLOGICAL STUDIES ON HOMOZYGOUS DWARFS. E. S. E. Hafez, D. W. Fletcher and C. C. O'Mary, *State College of Washington.*

Thirty-four Hereford homozygous dwarf calves and eight controls were available. The dwarfs exhibited different degrees of head abnormalities possibly as a result of different stages of development (pre-natal or post-natal) at the time the defective gene came into operation. Dwarfs had lower respiration rates (significant) than controls; rectal temperatures and pulse rates were identical. Among hematological values studied, the dwarfs showed lower blood hemoglobin, hematocrit and white count. The electrophoretic analysis of plasma proteins did not show characteristic patterns. There was no common cause of death (autopsy). Dwarfs were either bloater, pot-bellied or normal-bellied. There are possibly two bloat cycles in the bloater dwarf, one a diurnal cycle and the other recurring every 2–3 weeks. Normal-bellied dwarfs were less tolerant to bloat than bloater dwarfs. Protozoa in bloater dwarfs were either absent or in reduced number and showing sluggish motility. In non-bloated dwarfs and in control animals the protozoa were active and abundant. The fermentation rate (Warburg manometry) in the rumen of bloater dwarfs was at endogenous levels within 3 hours after feeding. In bloater dwarfs, the metabolic activity of the microbial population was less, but the potential activity per cell was apparently greater than in the normal rumen. In the presence of excess substrate (ground feed) the fermentation rate of rumen contents from bloater dwarfs was 26% greater than non-bloater dwarfs and normal controls.

13. INFLUENCE OF BREED OF SIRE AND LEVEL OF WINTERING ON GROWTH AND FEED-LOT PERFORMANCE OF CROSSBRED STEERS. J. D. Wright, M. Koger and T. J. Cunha, *University of Florida.*

The performance of steers produced by mating Brahman-Native cows (approximately ½ each) to bulls of four breeds was determined when fed as calves immediately following weaning, and when fed limited grain on pasture or fed in dry-lot

following wintering on low and intermediate nutritional levels. Average daily gains in lb. for the four breed groups were: 0.34, 0.19, 0.28, and 0.35 during the winter period; 1.9, 2.3, 2.5 and 2.3 on spring and summer pasture period; and 1.7, 1.9, 2.3 and 2.1 while on feed for steers sired by Angus, Brahman, Hereford and Shorthorn bulls, respectively. The breed x period interaction was significant for daily rate of gain. Carcass grades for the breeds were: 9.9, 8.1, 9.7 and 9.3, respectively; with 8 representing high Standard; 9, low Good and 10, average Good. Estimated net returns per steer expressed as deviations in dollars from the mean were: —1.95, —10.15, +7.65 and +3.25, respectively, for the four breed groups. Low level wintering proved to be less profitable than the intermediate level, with interaction of level of wintering and breed being non-significant for all of the items of performance studied. These studies would also indicate that steers with approximately ¾ Brahman breeding do not perform as well in the feed lot as steers with a lesser amount of Brahman blood.

14. EFFECT OF LENGTH OF FEEDING PERIOD ON HERITABILITY OF POST-WEANING GAIN OF BEEF CATTLE. C. A. Dinkel, *South Dakota State College.*

Four years' data on the post-weaning rate of gain of 149 bull calves sired by 22 bulls were analyzed by the method of least squares with constants fitted for sires, years, and inbreeding classes. Heritability of rate of gain for the three periods (140, 168 and 196 days) was calculated by the paternal half-sib method. Sire differences were highly significant in all periods; year differences were highly significant at 140 days and non-significant in the other periods; and inbreeding effects were highly significant at 196 days but non-significant in the other two periods. Heritability estimates after adjustment for inbreeding of the individuals were 0.45, 0.52, and 0.65 for the 140, 168, and 196 day periods, respectively, and the standard errors of these estimates are 0.22, 0.23 and 0.25 Since some of the calves were produced in single sire inbred lines, these estimates may be biased because of the confounding of line effect and sire effect. The data indicate that the phenotypic standard deviation decreases with the longer feeding periods; however, not to the extent that the advantage of higher heritability is overcome. Using the product of the heritablity estimates and the phenotypic standard deviations for each period as a measure of the progress to be made, selection on the basis of 140 day gain would make 79% of the improvement expected from the use of 196-day gain, and selection on 168-day gain 84%. However, selection on 140-day gain would make 94% of the improvement expected by selecting on 168-day gain. These relative figures are dependent upon the level of heritability and if the true values are different from the estimates obtained the advantage of the longer feeding might be quite different.

15. MULTIPLE SIRE MATING: THE EFFECT OF MATING BEHAVIOR, ORDER, FREQUENCY AND INTERVAL BETWEEN MATING ON MULTIPLE PATERNITY. L. J. Sumption and J. C. Adams, *Nebraska Experiment Station.*

Three experiments were conducted to determine the following proposed values of multiple sire mating (contrasted with single sire mating) in developing new lines of swine: (1) natural selection for breeding efficiency among both sires and dams, (2) production of a greater variety of gene combinations (multiple paternity within litters), (3) ease of mating large populations. Results supported the hypotheses. I. Ten sows mated to sires of four breeds. As many as three boars sired single litters, determined by color and anatomical differences among progeny. Effective matings occurred during 11 hours. II. Sires of five breeds and 43 Duroc gilts were mated in the following groups (a) multiple mating to five breeds, one day only (b) single mating, two successive days to two breeds, (c) double mating, Day I to breeds A

and B, Day II to breeds A and C. As many as four sires were represented in single litters. Progeny per sire within litters was not random but was not influenced by order of mating. Effective mating occurred 24 hours apart. Effective matings on Day II of estrus tended to produce larger litters than matings on Day I, but frequency of mating within days had no effect on litter size. III. Four boars each of three breeds were lot-mated to 17 gilts. Marked differences in mating behavior among both sires and dams were observed. Results indicate the value of multiple sire mating in reducing the contribution of inefficient breeders and increasing the variety of recombinations, of special importance in the small populations ordinarily developed.

16. SUMMER BREEDING PERFORMANCE OF SHEEP AS INFLUENCED BY LEVELS OF NUTRITION. D. M. Baird, W. E. Neville, Jr., and O. E. Sell. *Georgia Experiment Station.*

For 2 years, duplicate treatments of low (Bermuda pasture), medium (Bermuda pasture +2 lb. No. 2 alfalfa hay) and high (oats, ryegrass and cr. clover pasture followed by brown top millet +2 lb. No. 2 alfalfa hay +0.8 lb. oats/day) planes of nutrition were assigned to ewe groups on May 18 (breeding began June 8) and continued until the termination of the breeding season (Aug. 23). Ewes were allotted at random within age and breed classification. For low, medium and high plane groups, respectively, the av. initial wt. was 125, 127 and 123 lb. while the A.D.G. during the treatment period was —.01, 0.07, and 0.14 lb. All ewes appeared to be in good to excellent condition prior to and during the breeding season as well as during subsequent gestation. There was a total of 203 ewe observations, of which 81 were aged ewes (Hamp.-Col.-Dorset crossbreds), 68 two- to four-year-old Hamp. crossed on aged ewes, 39 two- to three-year-old Southwestern (Col. X Ramb.) and 15 purebred Hamp. ewes. Only rams which appeared fertile by semen examination at the beginning of the test were used. Rams were rotated between groups each 17 days. Results of X^2 analysis of lambs born from all ewes allotted and lambs born from ewes lambing did not indicate significant differences between planes of nutrition, breed groups, years or their interactions. Date of fertile service (service date which resulted in a lamb being born) on the above ewes (141) were available since raddled rams were used. Results of analysis of variance of these dates did not indicate significant plane of nutrition, breed of ewe (purebreds omitted) and year differences but did indicate a significant ($P<.01$) breed of ewe x plane of nutrition interaction. Other interactions were not significant.

17. INVITATIONAL PAPER—PROBLEMS AND EVIDENCE IN SWINE BREEDING. R. E. Comstock, *University of Minnesota.*

18. QUANTITATIVE INHERITANCE OF BODY SIZE IN MICE: REPEATED BACKCROSSING WITH SELECTION. C. K. Chai, *Roscoe B. Jackson Memorial Laboratory.*

An attempt to isolate genetic factors affecting body size in mice has been made by an experiment involving crossbreeding of Large and Small mice which differ extremely in body size. Results from the earlier crossbred generations have indicated segregation of genetic factors responsible for the difference and existence of some degree of dominance of plus factors over minus factors. Repeated backcrossing has been made to the Large and Small mice along with mass selection for large as well as for small body sizes in each backcross. A total of 1816 mice have been used from the parental strain to the 6th backcross generation. The 60-day body weight has been used as index of body size. The backcrosses to the Small mice selected for Large body size beginning from the 4th backcross generation showed no more reduction in mean body weight and a differential of approximately 1 gram was maintained Those selected for small body size approached the mean weight of the Small mice. The variances were in general as expected except those in the 5th and 6th backcross

generations selected for large size appeared smaller than expected. It is tentatively concluded that the Large mice do not carry minus factors which are not present in the Small mice. Single factors responsible for large body size have likely been isolated in the 4th to 6th backcrosses selected for large body size.

19. FEED LOT RESPONSE OF STEERS OF DIFFERENT BREEDS TO DIFFERENT RATIONS AND HORMONE TREATMENT. W. C. Burns, M. Koger, and C. M. Kincaid, *U. S. Department of Agriculture and Florida Experiment Station.*

Forty-one 15-month-old, light-weight steers of five different breeds were fed in dry lot for 112 days during the summer to determine the response from alfalfaleaf meal, stilbesterol and breed on gains and carcass quality. The fattening ration consisted of 2½ lb. 41% cottonseed meal plus ⅓ ground snapped corn, ⅓ citrus pulp, ⅓ citrus molasses, and Coastal Bermuda hay free choice. The feeding of 0.2 lb. daily of alfalfaleaf meal did not influence daily gain or carcass quality. An implant of 30 mg. stilbestrol significantly increased average daily gain 0.4 lb. above non-implanted steers, significantly decreased carcass grade by ⅓ grade and had no effect on tenderness. Steers fed 0.2 lb. alfalfaleaf meal with the implant responded similar to the steers given the implant alone. There was a highly significant difference among breeds on daily gain. The pounds of average daily gain were Santa Gertrudis, 3.1; Brahman, 2.7; Hereford, 2.5; Brahman-Angus, 2.3; and Angus 2.1. Differences in carcass grade among the breeds were highly significant the average scores being: Angus, 9.5; Hereford, 8.6; Brahman, 7.8; Santa Gertrudis, 7.8; and Brahman-Angus, 7.5. There was a significant difference among breeds in tenderness scores determined by the shear method. A higher score indicates less tender meat. The average scores were Hereford, 8.4; Angus, 8.6; Brahman-Angus, 8.8; Santa Gertrudis, 9.1; and Brahman, 12.3.

20. HERITABILITY OF TDN/cwt GAIN IN BEEF CATTLE THAT ARE FULL FED. J. A. Gaines, R. C. Carter, and C. M. Kincaid, *Virginia Agricultural Experiment Station and Agricultural Research Service USDA.*

The objectives of this study were (1) to estimate the effects of initial weight, years, total gain and breed on TDN/cwt gain of bulls and steers that were full fed, (2) to adjust the data for these effects, and (3) to estimate heritability of TDN/cwt gain. Data from individually feeding 276 bulls and 152 steers were used; the bull records covered a ten-year period and the steer records a six-year period. The bulls were fed in Front Royal and the steers were fed in Blacksburg, Va. The bulls were fed a ration of mixed hay and grain for 168 days; the steers were fed a similar ration for 200 days. Conventional least squares analyses were made to estimate the linear relationships between TDN/cwt gain (dependent) and the independent variables initial weight, year, total gain, and breed. R^2 was 0.76 in the steers and 0.67 in the bulls, indicating that a large portion of the variance in TDN/cwt gain was linearly associated with initial weight and total gain. Estimates of the effects of initial wt. and total gain show that the lighter animals required significantly less TDN/cwt gain than the heavier ones, and the animals that made the larger gains did so on significantly less TDN/cwt gain than the ones that made the smaller gains. Variance component analyses of the adjusted data yielded heritability estimates of 0.17 in the steers and 0.63 in the bulls.

21. GENETIC AND ENVIRONMENTAL FACTORS AFFECTING WEANING PERFORMANCE OF CALVES AT THE RANGE CATTLE STATION. W. L. Reynolds, W. G. Kirk, F. M. Peacock, and M. Koger, *University of Florida.*

A study was made of 2528 calves of Brahman and Shorthorn breeding and crosses involving Brahman, Shorthorn, native, Angus, Hereford, and Santa Gertrudis.

The average 205-day weaning weight for all calves was 407 lb., with a 34 lb. advantage for steer calves. Calves from 2-, 3-, and 4-year-old dams were 67, 35 and 15 lb. lighter, respectively, than calves from dams 5 to 12 years of age. Calves born in April, May, and June were 8, 25, and 38 lb. lighter than the average of calves born in January, February and March; whereas, calves born in the summer months were 60 lb. lighter. Adjusted weights of calves sired by bulls of different breeds were as follows: Brahman, 431; Hereford, 441; Shorthorn, 448; ½ Shorthorn–½ Brahman, 453; Santa Gertrudis, 453; and ¾ Brahman–¼ Shorthorn, 469. 2341 calves containing Brahman breeding were classified on proportion of Brahman blood into one-eighth, more than one-eighth, but less than one-half, one-half, more than one-half but less than seven-eighths, seven-eighths and pure Brahman breeding. Adjusted mean weights were 419, 452, 438, 447, 428, and 408 lb., respectively. 1470 calves containing Shorthorn breeding were classified in the same manner with adjusted weights of 434, 449, 462, 454, 407, 392 lb. Dams with Brahman breeding classified into groups with less than one-half, one-half, one-half through seven-eighths, and pure Brahman breeding produced calves with adjusted weights of 425, 459, 432 and 460 lb. Adjusted weights of calves from dams of Shorthorn breeding classified in the same manner were 439, 449, 416 and 389 lb.

22. VARIATION IN GROWTH RATE BETWEEN SELECTED LIKE-SEXED TWINS AS COMPARED TO RANDOMLY SELECTED LIKE-SEXED LAMBS. Don G. Brothers and J. V. Whiteman, *Oklahoma State University*.

Variances between selected like-sexed twin lambs were compared to variances among randomly selected like-sexed lambs of similar weight to estimate the experimental efficiency obtainable by the use of twins in growth studies. The lambs were all of similar breeding and were raised under similar conditions at the Fort Reno Experiment Station over a three-year period. Nineteen pairs of male and 13 pairs of female twins within 6, 4 and 2 lb. of each other were selected when they weighed approximately 50 lb. Like-sexed random lambs were also selected within the same weight ranges simultaneously. Average daily gains to marketing, carcass yields and grades were obtained. Twin efficiency values were calculated for these characteristics by the mean square comparisons of among random individuals/within pairs of twins. The efficiency values for daily gain were 1.68, 3.70 and 5.42 for males and 2.00, 1.62 and 2.14 for females when pairs were selected within 6, 4 and 2 lb. of each other, respectively. Values for carcass grade were 1.84, 1.70 and 1.51 for males and 6.12, 7.48 and 9.44 for females. For carcass yield the males had values of 1.17, 1.00 and 1.60 for the 6, 4 and 2 lb. selection ranges. The values for females were all less than one. Although quite variable, these estimates indicate selected like-sexed twin lambs may be useful in reducing the experimental error.

23. EVALUATION OF A METHOD FOR MEASURING STAPLE CRIMP OF GREASE LOCKS FROM INDIVIDUAL FLEECES. Mary E. Hourihan, Walter R. Harvey and Clair E. Terrill, *United States Department of Agriculture, ARS*.

A reasonably accurate, fast and inexpensive method of quantitatively measuring crimp in individual fleeces would be valuable in a selection program. The method used in this study involved separating a subsample of wool from a lock, placing this subsample between two slides, projecting the crimp image, selecting a distinct crimp pattern and drawing the crimp on paper. After crimp width and depth were measured from the drawings, width-to-depth ratio and the number of crimps per inch were calculated. Grease wool locks were randomly chosen from the shoulder, back, and thigh of 13 Merino and 10 Shropshire yearling ewes. A total of 552 drawings were prepared by each of two operators. The importance of variability due to ewes, locations on the ewe, locations on the lock, slide preparing operators, drawing operators,

subsamples within locks, and interactions were evaluated by the analysis of variance. Differences in number of crimps per inch due to ewes, locations on the ewe, locations on the lock, and the interactions of ewes with fleece and lock locations were highly significant statistically. When two operators drew the crimp from the same projected area, no significant differences between operators occurred. However, when each operator was allowed to choose the area and crimp pattern for drawing, one operator consistently found patterns with more crimp per inch than did the other. An interaction between preparing operators and ewes also existed. The coefficients of variation for number of crimps per inch were 7.2% and 12.2% for the Merino and Shropshire breeds, respectively.

24. A STUDY OF VARIATION IN LENGTH OF INDIVIDUAL FIBERS FROM FOUR LOCATIONS IN GREASE WOOL LOCKS. Walter R. Harvey, Mary E. Hourihan, and Clair E. Terrill, *United States Department of Agriculture, ARS.*

Fifty locks were randomly selected from each of 38 Rambouillet ram fleeces shortly after shearing and were divided randomly into two groups of 25 locks each. Operator 1 carefully selected two fibers at random from each of four equidistant locations on each lock in Group A. Operator 2 followed the same procedure in Group B. Unstretched and stretched fiber lengths were measured in centimeters. Differences among randomly selected fibers from the same lock were the most important, accounting for 61.5% and 59.7% of the total variation in unstretched and stretched fiber length measurements, respectively. Variability among locks within rams and ram differences accounted for 17.8% and 12.2% of the variation in unstretched length measurements and for 13.8% and 9.2% of the variation in stretched length measurements, respectively. The difference between operators was small for unstretched fiber length measurements (2.1%) but accounted for 12.0% of the total variation in stretched fiber length measurements. The interactions of rams with operators and locations on the lock with locks were significant statistically but accounted for only 1.7 to 3.4% of the total variability. Coefficients of variation were 19.4% for unstretched and 20.7% for stretched fiber length measurements. With 50 locks per ram and eight fibers measured per lock, the standard error of ram means was about 2%. Reducing the number measured to only one fiber per lock would increase the standard error to about 3%, which would also be expected if three fibers from each of 25 locks were measured per ram.

25. RECENT DEVELOPMENTS IN PROGENY-TESTING DAIRY SIRES IN NEW ZEALAND. S. R. Searle, *New Zealand Dairy Board, Wellington, and Cornell University.*

Since 1950 a dairy sire has been judged by comparing his daughter records with contemporary records of herd mates. The age corrected daughter average is expressed as a deviation from the expected daughter average as obtained from the regression E (bull's daughter average) = 76 + .75 (mature cow average), mature cows (4–9 year-olds) being the herd mates. This difference is known as the "difference from expectancy"; it is used for both the predominantly one-herd bulls used in natural service (approximately 3000 proofs annually) and for those used in A.B., where it is averaged over all herds in which a bull has daughters. To take account of the widely differing numbers of daughters and lactations in natural proofs, the "difference from expectancy" is expressed as a "rating," by multiplying it by a factor which is one-half of its regression on the sire's additive genetic value. These factors show that when the number of daughters in a natural proof has reached 20, further lactations from the same daughters yield more information than do additional daughters. The factor for a bull used in A.B. is $\frac{n}{n + 15}$, n being the number of daughters, and assuming one lactation per daughter, each in a different herd. Age correction factors for the

2- and 3-year-olds have been additive, but starting this year they will be based on herd level. The expectancy (regression) line will then use the result that 90% of the difference between herd production levels is reflected in the production of a sire's daughters.

26. A COMPARISON OF SIRE TESTS MADE AT SPECIAL DANISH PROGENY TESTING STATIONS WITH TESTS MADE IN FARMER HERDS. R. W. Touchberry and K. Rottensten, *University of Illinois and Royal College of Agriculture and Veterinary Medicine, Copenhagen, Denmark.*

The data for this study consisted of the first lactation butterfat records of 5454 daughters of 305 Red Danish Milkrace sires tested at the Danish progeny testing stations from September 1, 1948, to September 1, 1956, and the first calendar-year butterfat records of 3270 daughters of 110 of these same sires as tested in farmer herds. For the testing station data the between progeny groups within station years and the within progeny groups components of variance were 229 and 1280, respectively. After adjusting the data for age at calving and days in milk, the components were 223 and 1140, respectively. The heritabilities derived from the unadjusted and adjusted components were 0.61 and 0.65. In analyzing the data from farmer herds each daughter's record was expressed as a deviation from the respective calendar-year average of the herd in which the record was made. The between and within sire components were 47 and 887, respectively, and the heritability was 0.20. The correlation between the tests at the special station and those in farmer herds was 0.16.

27. MILK AND BUTTERFAT PRODUCTION OF NATURALLY AND ARTIFICIALLY SIRED COWS IN VIRGINIA HERDS. N. R. Thompson, V. L. Baldwin, G. C. Graf, *Virginia Polytechnic Institute.*

Lactation records of cows in Virginia DHIA herds were adjusted to 305-day mature equivalents, then sorted according to sire of cow within herd and year-season of calving (March to August and September to February). Records made at all ages were used. Average milk and butterfat production of each naturally sired (NS) group was compared with the corresponding artificially sired (AI) group (same herd and year-season of calving). Some comparisons were made between NS groups and AI groups by individual sires. Weighted summaries of the differences were made over all herds and year-seasons. In the Guernsey breed, the pooled AI groups averaged 12 lb. more milk and 1 lb. less butterfat than the NS groups. Individual Guernsey AI sire groups ranged from +1622 lb. milk and +82 lb. butterfat to —1973 lb. milk and —96 lb. butterfat. In the Holstein-Friesian breed, the pooled AI groups averaged 9 lb. more milk and 7 lb. more butterfat than the NS groups. No breakdown by individual Holstein sires has been made as yet. However, in a breakdown by year-seasons (and over all sires), the differences between AI and NS groups in the Holstein-Friesian breed ranged from +974 lb. milk and +39 lb. butterfat (in favor of the AI groups) to —527 and —25.

28. VARIATION IN WEIGHT-CONSTANT BODY LENGTH MEASUREMENTS OF HEREFORD BULLS. R. R. Woodward and F. J. Rice, *United States Range Livestock Experiment Station, U.S.D.A.*

Selection for increased body length appears to have merit as a method of beef carcass improvement. Variation in the length measurements (anterior edge of the scapula to posterior portion of the tuber ischii) of 55 yearling Hereford bulls was determined within 25 lb. weight groups ranging from 851–950 lb. Simultaneous measurements were made on both sides in an attempt to reduce error due to linear deviation. Repeatability of the mean of two successive trials was 0.90. The maximum range in body length was found in the 876–900 lb. weight group. There was a 10.7 cm. range,

representing a variation of 6.4% of the average body length of the weight class. Standard deviations, listed by ascending weight groups, were 3.4, 2.9, 3.1 and 3.2 cm. A significant positive correlation was found between body length and birth weight (0.254). Positive, but non-significant, correlations were found between body length and 180-day weight (0.055) and average daily gain on test (0.152).

29. GROWTH FROM BIRTH TO WEANING IN BEEF CALVES AS AN INDICATION OF FUTURE PERFORMANCE. S. W. Sabin, P. O. Stratton and N. W. Hilston, *University of Wyoming.*

One-hundred eighty-five calves, Shorthorn, Hereford and Angus, born in three consecutive years, were used to test the possibility of selection at weaning for future performance as measured by gains during, and weight and score at the completion of, a 168-day feeding trial. Analysis of variance of multiple regressions of the three future performance criteria provided R^2 values of 0.61, 0.87, and 0.38 respectively. Each is significant at $P<.05$. There was a general failure of preweaning weights, measures, and environmental influences to predict future scores and future gains. The regression of final weight was highly significant; only age at weaning and chest depth at weaning failed to give a significant relationship. Weaning score was the only independent variable significantly associated with final score. Physiological age differences due to sex and age of dam were responsible for the majority of the results. Yearly influences were at a minimum. Bone measurements were capable of predicting future size but not future weight. Condition and conformation scores at weaning are indicators of future scores. Skeletal size and development are not measured accurately by weight.

30. A STUDY OF THE EFFECTS OF BIRTHWEIGHT AND QUANTITY OF MILK FED ON GAIN OF YERLIKARA CALVES. Macit Eker, *Ankara University, Turkey.*

Data have been collected from the records of an experimental and breeding herd of native black cattle belonging to the Department of Animal Husbandry, College of Agriculture, Ankara. The records extended from 1946 to 1957. The grain feeding level and the management were similar during different years. The birthweights of 64 females varied between 11.2 and 24.0 kg. and averaged 17.79 $\pm$ 0.33. The birthweights of 53 males were between 13.0 and 28.0 kg. and averaged 18.77 $\pm$ 0.44. The average liveweights at the weighing intervals were compared with the standards set up for Jersey calves by the Missouri Experiment Station. The gains of Yerlikara calves were higher than Jersey's until the first 90 days of age. For the subsequent periods, gain was in the favour of Jersey calves. The quantity of milk fed varied from 200 to 2237 l. and averaged 867 l. for females, 790 l. for males. The milk feeding periods were 186 and 165 days, respectively. There was no significant difference between birthweights of both sexes and years. For that reason the material was calculated and evaluated together. The correlation coefficients between birthweight and daily gain were 0.4107 $\pm$ 0.077 and between amount of milk and daily gain, 0.4165 $\pm$ 0.076 at 180 days of age. The coefficients of multiple determination (R^2) for birthweight and milk fed on daily gain were 0.3239 or 32.39%, and other uncontrolled factors ($1-R^2$) were 0.6761 or 67.61%. The coefficient of determination of birthweight, without milk fed, on daily gain was 0.1513 or 15.13%; and for milk fed, without birthweight, was 0.1560 or 15.60%. The coefficient of joint determination was 0.0165 or 1.65%.

31. CALF PRODUCTION UNDER FOUR PASTURE SYSTEMS. W. G. Kirk, F. M. Peacock, E. M. Hodges and M. Koger, *Range Cattle Experiment Station, Ona, Florida.*

A three-year study was undertaken to determine the cost of raising calves to 7.5 months under different pasture conditions. Four herds were made up as follows: 60

cows of Brahman and Shorthorn blood and their crosses in each of Herds 1, 2 and 3 and 58 to 65 grade Brahmans in Herd 4. Pastures consisted of: Herd 1, 800 acres native range; Herd 2, 75 acres improved and 325 acres native pasture; Herd 3, 75 acres pangolagrass, 18 acres of which were over-planted with white clover and irrigated; Herd 4, 105 acres pangolagrass. Herd 1 was fed protein pellets in two winters, but the other herds obtained all their feed by grazing. All pastures were grazed rotationally with some deferred grazing for Herds 2, 3 and 4. Capital outlay per cow for Herds 1, 2, 3 and 4 was $591.00, $460.17, $386.00 and $349.00, respectively. Charges included interest on investment, taxes, care of herd, bull expense, mineral and supplemental feed, spray, fertilizer, irrigation, death and replacement costs. Yearly cost per cow on native range was $47.48; combination of native and improved pasture, $56.24; pangolagrass plus clover, $68.28; and pangolagrass, $66.02. Average weaned calf crop for three years was: Herd 1, 62%; Herd 2, 81; Herd 3, 82; and Herd 4, two years, 85%. Yearly calf production per cow for Herds 1, 2, 3 and 4 was 230, 348, 397 and 400 lb., respectively, and weaning cost per 100 lb. was $20.64; $16.16, $17.20 and $16.51 for the four herds.

32. THE RELATIONSHIP OF SERUM PROTEINS TO RATES OF GAIN IN IMMATURE BEEF CATTLE. H. O. Kunkel and George G. Green, *Texas Agricultural Experiment Station.*

Serum proteins from cattle in gaining evaluation tests were fractionated into a principally globulin and an albumin fraction with Na_2SO_3 at a final concentration of 19%. Small ($R = 0.3–0.6$), but statistically significant, multiple coefficients of correlation between the serum protein fractions and rates of gain were obtained with Angus and Hereford cattle. The evidence indicates that a part of the globulin fraction as well as a part of the albumin fraction is related to gaining ability. Preliminary evidence suggests a positive relationship between the glutathione concentration in the erythrocyte and the albumin fraction, and that this interrelation affects the interpretation of the serum protein—gain relationship. The serum protein-bound iodine (PBI) is correlated to some extent with both fractions; thus, the serum proteins must be considered in evaluating the physiological significance of varying levels of serum PBI.

33. RELATIONSHIP OF GRADE AND PRICE AT GRADED PRODUCER-SPONSORED SALES IN MARYLAND. J. R. Ferguson, B. T. Whittle and A. R. Meyer, *University of Maryland.*

The relationship of grade and price per cwt., of feeder calves, feeder pigs and market lambs was studied. All animals were sold at public auction by grade in producer-sponsored special sales. Price relationships were calculated for each sale and expressed as a percentage of the prices received for choice grade animals. The values for each sale were of similar magnitude and were averagd as follows: (A) 5,672 feeder calves, autumn sales (5 years and 6 sales)—Fancy 127%, Choice 100%, Good 91%, Medium 83%; (B) 2,037 feeder cattle sold in spring sales (4 years and 4 sales)—Fancy 106%, Choice 100%, Good 97%, Medium 91%; (C) 4,633 feeder pigs (2 years and 4 sales)—Choice 100%, Good 94.5%, Medium 87.7% (no significant difference between spring and autumn sales was noted); (D) 753 market lambs (1 year and 3 sales)—Prime 103%, Choice 100%, Good 92%, Medium 79%. The magnitude of price difference between grades in the case of cattle was approximately twice as much in fall sales as in spring sales. In all cases the price spread for good and medium heifers was greater than for steers. Good and medium feeder calves were discounted approximately 9% per grade in autumn sales and 3%–4% per grade in spring sales. Good and medium feeder pigs were discounted approximately 6% per grade. Good and medium lambs were discounted 8% and 20%, respectively. Weight and grade were positively related. The average weight difference between grades amounted to 5%–10%.

34. THE AMOUNTS OF FEATHERING AND OVERFLOW AS RELATED TO THE MARBLING CONTENT OF PORK CARCASSES. R. G. Kauffman, R. W. Bray and E. J. Briskey, *University of Wisconsin.*

Feathering is the striated deposits of fat between the ribs, and overflow is that fat over rib cage area. These fatty deposits are often used to predict amounts of marbling in meat animal carcasses; however, statistical validity of this practice has not been established. It was the purpose of this study to investigate the potential of feathering-overflow as an indicator of marbling in pork. Seven loin marbling, five ham marbling and five feathering-overflow picture scores were established to identify the existing amounts of fat in the loin, ham and rib cage, respectively. The picture scores were compared to 622 pork carcasses of which 311 originated from carcass contests, 197 selected at random in a local packing plant and 114 from known history hogs representing several breeds. Results indicated a statistical relationship between amounts of feathering-overflow and marbling in the loin and ham; however, when fatback thickness was correlated with feathering-overflow, no relationship existed. Analysis of 508 carcasses showed the correlation coefficient ($r = .260$) to be highly significant when feathering-overflow was compared to loin marbling. The known history group of carcasses duplicated this significance as indicated by a positive correlation of 0.330. Ham marbling was also found to be highly significant when correlated to feathering-overflow. Even though an adequate degree of significance was obtained in this investigation, the low coefficients tend to leave doubt as to the validity of using feathering-overflow scores as a sole source of predicting the amounts of marbling in pork.

35. ANATOMICAL, PHYSICAL, CHEMICAL AND COOKING CHARACTERISTICS OF PORK LOIN AS AFFECTED BY FEEDING LEVELS. E. S. E. Hafez, Marion Jacobson, M. E. Ensminger, W. E. Ham and Margaret M. Weller, *State College of Washington.*

Palouse gilts were divided into two groups; one group was full fed from weaning to 150 lb., and the other group was fed 70% of full feeding. After six generations, one-half of the pigs in each group were shifted to the other plane of nutrition, thus forming four groups; high-high (HH), low-high (LH), low-low (LL) and high-low (HL). Nineteen F_{10} gilts were slaughtered and the right loins dissected to tissue components. The left loins were used for physical, chemical and cooking studies. The feeding level had no effect on proportion of wholesale loin/carcass weight (range 23.61 to 25.1%), or the weight of *longissimus dorsi*/total lean of loin (range 48.79 to 54.39%). *Longissimus dorsi* weighed 4.28 (LL), 3.87 (HL), 5.36 (HH) and 5.12 lb. (LH), the differences being significant. The surface area of *longissimus dorsi* section was 4.98, 4.49, 5.26 and 5.46 sq. in., respectively. Width:length ratio, as measured by the "lean-square meter", showed large individual differences. Refractive index and iodine number of backfat was not affected. Ether extract in dry matter of *longissimus dorsi* was twice as much in high planes as in low planes. The nutritional level had no effect on shear force values for raw or cooked lean, on color (Rd, a+, b+ or hue) of dark or light lean, on drip loss (range 6.7 to 8.7%) on evaporation loss (range 16.1 to 18.9%) from roasts fresh or frozen, or on palatability (scores of juiciness, flavor, and tenderness by taste panel). There were considerable individual variations.

36. THE EFFECT OF HIGH PROTEIN, HIGH FAT AND HIGH CARBOHYDRATE RATIONS ON THE WATER-BINDING PROPERTIES OF PORK MUSCLE. E. J. Briskey, R. W. Bray, W. G. Hoekstra, P. H. Phillips and R. H. Grummer, *University of Wisconsin.*

Forty Poland China barrows (185–190 lb.) were allotted into four lots of 10 pigs each. To a 14% protein, corn-soybean oil meal ration the following additions

were made at the expense of corn: Lot I—no addition; II—28.5% tankage, 10% dried skimmilk and 25.75% lard; III—15% lard and 25% sucrose; IV—50% sucrose. The hogs were individually fed these rations for a 2-week period after which five hogs from each lot were exercised to exhaustion immediately prior to slaughter. Samples of the gluteus medius, biceps femoris, rectus femoris and pectoralis profundus muscles were excised from the carcasses at two intervals (2 minutes after slaughter and after a 24-hour chill). The following water-binding and associated properties were determined for each muscle: Expressible water, pH, glycogen, fat, total moisture, visual color and firmness classification and myoglobin concentration. The fresh samples of the gluteus medius and biceps femoris from the unexercised hogs of Lots I and II possessed significantly lower glycogen concentrations than those of Lots III and IV. The chilled samples of the gluteus medius and biceps femoris muscles of the unexercised hogs in Lot II possessed a significantly darker color, lower expressible water and higher pH value than the unexercised hogs of Lots III and IV. These rations were not as effective in altering the characteristics of the rectus femoris and pectoralis profundus. The exercise treatment significantly decreased the fresh glycogen concentration, increased the color and firmness rating and raised the pH for the biceps femoris and gluteus medius from all lots. Neither ration nor exercise had any significant effect on the characteristics of the pectoralis profundus.

37. RELATIONSHIP BETWEEN TISSUES OF THE HAM, THE CARCASS AND THE EMPTY BODY OF SWINE. S. E. Zobrisky, H. D. Naumann, A. M. Mullins and D. E. Brady, *University of Missouri.*

Physical separation data from 150 hogs weighing from 10 to 400 lb. were used to determine the relationships between the major tissues of the ham, carcass and empty body. Examination of the data revealed that the lean, fat and bone of the empty body, carcass and ham increased in a definite and similar pattern during growth and fattening. The quantity of protein (N x 6.25) also increased in a similar manner. The percentage increase of total carcass fat and total ham fat, in relation to empty body weight, was very similar. The increase of subcutaneous fat of the carcass and ham and the increase of carcass lean and ham lean, in relation to the empty body weight, was likewise very similar. The body protein increased proportional to 0.89 units per unit increase of empty body weight.

38. EFFECT OF ELECTRIC SHOCK TREATMENT AND/OR EFFECT OF FEEDING SUGAR PRIOR TO SLAUGHTER ON CERTAIN CARCASS CHARACTERISTICS OF SWINE. P. K. Lewis, Jr., C. J. Brown and M. C. Heck, *University of Arkansas.*

Forty market-weight hogs were separated according to weight and sex into 10 outcome groups and were allotted at random to four treatments in a 2 x 2 factorial experiment. The four treatments were (1) control, (2) addition of 10% brown sugar to the drinking water for 48 hours, (3) stress received from periodic electric shock for approximately 5 hours prior to slaughter and (4) a combination of the addition of sugar to the drinking water and stress from electric shock during the preslaughter period. Treatment 2 significantly increased the weight of the hogs by 1.5%. There was no significant effect of sugar-feeding and/or electric shock treatment during the 5-hour period on the live shrink of these hogs. These four treatments did not significantly affect the liver weight, dressing percent, percent of total primal cuts or the 24-hour chill shrink of the carcass. Sugar-feeding significantly decreased the pH of the *longissimus dorsi, psoas major* and *quadriceps femoris;* and electric shock treatment significantly increased the pH of these muscles. Sugar-feeding and/or electric shock treatment did not affect percentage of moisture (expressed on a fat-free and carbohydrate-free basis), protein or ash (both expressed on a fat-free, moisture-free and

carbohydrate-free basis) of these muscles; sugar feeding increased their dry matter loss from cooking ($P<0.10$), but not their water loss; electric shock treatment decreased both.

39. STABILIZATION OF HOG CARCASS FATS BY THE ADDITION OF ANTIOXIDANTS TO THE RATION. G. P. Lynch, G. C. Anderson, and W. R. Lewis, *West Virginia University.*

Two feeding trials were conducted with four antioxidants added separately to a standard hog finishing ration in an attempt to increase the stability of the carcass fats. After slaughter, a sample was taken from the belly area of each hog and rendered at 180° C. in an atmosphere of nitrogen. The rendered fat was subjected to an accelerated stability test in an oven at 100° C. Addition of Antiozonant 288 (N,N′-dioctyl-p-phenylenediamine) to the ration at either the (1) 0.025% or the (2) 0.1% level produced a significant increase in the induction period of the rendered fat. The average induction period for the control group was 12 hours and for the two treatments were (1) 53 hours and (2) 104 hours. For groups fed 0.0, 0.025, or 0.10% Santoquin (2, 4-trimethyl-6-ethoxyquinoline) the average induction periods were 12, 14, and 16 hours, respectively. These differences were not statistically significant. Quercetin (3,3′,4′,5,7-pentahydroxyflavone) at the 0.025 or 0.1% level or dihydroquercetin at the 0.2% level in the rations did not increase the induction period by more than 2 hours. No toxicity symptoms were noted for any of the antioxidants at the levels fed, but additional toxicity evaluation is needed.

40. SOME RELATIONSHIPS BETWEEN LIVE ANIMAL MEASUREMENTS AND CARCASS CHARACTERISTICS OF LAMB. J. R. Stouffer, D. E. Hogue, D. H. Marden and G. H. Wellington, *Cornell University.*

Thirty-four lambs were used in a study to determine relationships between measurements on the live animal and carcass characteristics, and between carcass characteristics and tenderness. The thickness of the loin muscle and fat was measured on each animal before slaughtering by probing with a needle at the last rib. Dressing percent, carcass grade, external fat thickness, marbling score, loin depth, rib eye width, and rib eye area, were determined on each carcass. The Warner-Bratzler Shear was used to determine the tenderness of the cooked rib chops. Average dressing percent, average fat thickness, average marbling score, and average shear value were, respectively, for Prime, 55.0, 0.29, 10.5, and 8.5; for Choice, 52.2, 0.28, 9.4, and 7.6; for Good, 50.6, 0.15, 7.8, and 9.9; for Utility, 47.4, 0.12, 5.5, and 12.3. Correlation coefficients for depth of loin muscle and fat on the live lambs were +.583 with carcass loin depth, +.616 with carcass rib eye width, and +.420 with rib eye area. Correlation coefficients for marbling score were +.577 with dressing percent, +.715 with carcass grade, +.493 with external fat thickness, and −.252 with shear force value. All of the correlations were significant except marbling score with shear force value.

41. EFFECTS OF FEEDING AND IMPLANTING STILBESTROL UPON THE QUALITY AND PALATABILITY OF THE CARCASS. D. L. Mackintosh, R. A. Merkel, T. D. Bell, T. L. Hall, Dorothy Harrison, and Lois Anderson, *Kansas State College.*

Two years work is reported, including a total of 80 wether lambs. Four lots of 10 each were selected each year from lots of 50 lambs for carcass observations relative to the influence of using stilbestrol upon the quality and the palatability of the carcass. Lot I served as a control, Lot II received 6 mg. stilbestrol implants; Lot III, 2 mg. stilbestrol per day in the feed, and Lot IV received a commercial stilbestrol pre-mix feed. The control lambs had the highest dressing percent, the lightest

livers, lowest liver glycogen and highest liver fat; also the highest ether extract of the rib eye, indicative of marbling. The lots receiving 2 mg. stilbestrol per day in the feed, had the highest liver weight, liver fat and heaviest pelts. The lambs with the implants had the most outside covering and graded highest. The lambs receiving the pre-mix had the thickest covering over the hotel rack (1956) but the poorest covering otherwise. They also had the lowest amount of ether extract in the rib eye, lowest volume of press fluid, lowest press fluid nitrogen, and highest percent of N.P.N. in the total nitrogen in the press fluid. All lambs receiving stilbestrol pelted much harder than controls. No stilbestrol residue was found in the rib eye, backfat or liver in any of the lots. Cooking time, total cooking losses, and palatability of the roasted legs were not affected by the feeding or implanting treatments.

42. BEEF ACCEPTABILITY AS RATED BY A PANEL OF FAMILIES AND THE WARNER-BRATZLER SHEAR, USING LOIN STEAKS AND CHUCK ROASTS FROM CATTLE OF KNOWN HISTORY. G. T. King, O. D. Butler and R. L. Simms, *Texas Agricultural Experiment Station.*

The acceptability of two cuts, beef loin steaks and chuck roasts from cattle of known history, as rated by a panel of 40 families and by the Warner-Bratzler Shear, was studied. Fifty-seven cattle, ranging in age from 5.9 to 166.0 months, graded U. S. Canner through U. S. Prime, and from four feeding methods were used. The family panel was a random sample of 40 families from the Texas Agricultural Experiment Station payroll. There was no significant difference in eating acceptability from cattle from grazing, growing or fattening rations. Animal age had a significant negative effect on eating acceptability, and carcass grade and Warner-Bratzler Shear values increased with increased age. Variation between animals and variation between families had a highly significant effect on eating acceptability scores. Variation between animals had a highly significant effect on shear values. These families showed little discrimination in rating steaks and roasts from the upper four grades. Beef acceptability scores were influenced by factors other than animal variation. Family repeatability estimates ranged from —.672 to .997. Differences in left and right cuts were not significant. The Warner-Bratzler Shear was a reliable measure of beef acceptability.

43. RELATIONSHIP OF LIVE ANIMAL MEASUREMENTS TO VARIOUS CARCASS MEASUREMENTS IN BEEF. L. E. Orme, A. M. Pearson, L. J. Bratzler and W. T. Magee, *Michigan State University.*

In the past, major emphasis has been placed on either the use of visual estimates in the evaluation of cattle from birth to slaughter, or solely on the evaluation of the carcass with no particular attempt to relate carcass traits to those of the live animal. This study was undertaken to correlate objective and subjective live animal evaluation and in turn to correlate each of these to objective measurements and grade of the carcasses from the same live animals. Thirty-one steers were included in this study. Each steer was subjectively evaluated for 24 traits and objectively measured at 32 different locations. Seven carcass measurements were subsequently taken of each carcass along with such additional items as grade, dressing percentage, rib-eye area and fat covering at 12th rib. The relationships between subjective live animal scores and comparable live animal measurements were quite low in most cases; whereas, the correlation coefficients between subjective live animal scores and actual values for such items as rib-eye area, fat thickness at 12th rib and dressing percentage were highly significant. Various objective live animal measurements showed a high relationship to comparable carcass measurements. Such live animal measurements as circumference of fore and hind flank, circumference of middle, circumference of round above the hock; width of rump; and live weight were all significantly related to rib-eye area. When calculated with live weight constant, standard partial regression

coefficients of .89, .57, .58 and —.57 were obtained for circumference of fore and hind flank, circumference of middle and circumference above the hock, respectively.

44. SOME EFFECTS OF TYPES AND BREEDS OF CATTLE ON BASIC CARCASS CHARACTERISTICS. J. W. Cole, C. M. Kincaid and C. S. Hobbs, *University of Tennessee.*

Detailed slaughter, offal, physical, chemical and organoleptic data were obtained from 32 Holstein, Jersey, Guernsey, Brahman, Brahman crosses, Angus and Hereford steers. These animals were full-fed from about 2–4 months of age to approximately 900 lb. body weight, and were given identical treatment on all other factors, such as preslaughter fasting. Highly significant differences were observed for most slaughter characteristics including dressing percentage, U.S.D.A. grade, percentage of hide, caul fat, ruffle fat, viscera, G.I. tract (*Brahma* 10.2% as compared with 16.1% for Jerseys) and others. The differences in cutting yields of the various wholesale cuts were small, although the dairy breeds had the highest total mean percentage of round, loin and rib and the lowest percentage of thin cuts. The differences among breeds in size of loin eye, fat covering over the 12th rib, other linear measurements, percentage of protein, fat and moisture, and separable fat, lean and bone were all highly significant. British breeds were more tender than Brahman and Brahman crosses with dairy breeds having shear test ratings between these two groups. In paired comparisons tests for preference of the rib roasts, taste panel preferences indicated considerable variability among steers of the same breed and suggested there may be one or more factors not related to fatness which influence the eating quality of beef. Cooking losses were lowest for the dairy breeds.

45. SIMPLE CORRELATIONS BETWEEN CARCASS GRADE, MARBLING, ETHER EXTRACT OF LOIN EYE AND BEEF TENDERNESS. A. Z. Palmer, J. W. Carpenter, R. L. Alsmeyer, H. L. Chapman and W. G. Kirk, *Florida Agricultural Experiment Station.*

Short loin steaks were removed from 536 carcasses of known feeding and management background after the carcasses had been chilled for 48 to 72 hours after slaughter. The steaks were cut one-inch thick and broiled medium-well done. Tenderness values as determined by Warner-Bratzler Shear and by taste panel were related to carcass grade, degree of marbling, area and ether extract of the *longissimus dorsi* muscle at the 13th rib. Highly significant coefficients of correlation were obtained between grade and marbling, ether extract in the *L. dorsi,* panel tenderness, shear force values and rib eye area. Grade accounted for around 8% of the variability in panel tenderness. Highly significant correlations were also obtained between marbling and ether extract in the *L. dorsi,* panel and shear force tenderness values, and rib eye area. Marbling accounted for around 11% of the variability in panel tenderness.

46. FACTORS RELATED TO TENDERNESS AND JUICINESS OF BEEF. Ferne Bowman, Edna Page, M. H. Hazaleus and H. H. Stonaker, *Colorado State University.*

To ascertain the relation of fat to quality of beef, data were collected on steaks from carcasses of experimental cattle (steers and heifers) during a period of 3 years. Adjacent center steaks 2 in. thick were cut from the frozen *longissimus dorsi* muscles from the 10th, 11th, and 12th rib sections of experimental carcasses. Steaks were defrosted and then specific gravity was determined by air displacement. Steaks were thereafter broiled, and samples from each steak were evaluated for appearance, aroma, flavor, juiciness and tenderness by a panel of five judges. Shear force (tenderness) of steaks was ascertained by a Warner-Bratzler Shear apparatus. Also, moisture, fat and pH were determined. Analysis of variance tests of data determined correla-

tion coefficients between: Specific gravity and percent fat, juiciness and percent fat, specific gravity and tenderness, tenderness and external fat measurements, specific gravity and external fat measurements, tenderness and shear force, tenderness and juiciness, percent fat and external fat measurements, and percent fat and tenderness. When all variables were considered, correlations between tenderness and juiciness were statistically significant. Such factors as experimental animal, sire, amount of external and/or internal fat and shear force were closely related to tenderness and juiciness of samples. Although two of the correlation coefficients between specific gravity and percent fat and one between specific gravity and tenderness were significant in 1957–1958, all other correlations were not significant.

47. THE RELIABILITY OF THE MEASUREMENT OF MARBLING DEPOSITS IN BEEF RIBEYE MUSCLE AS DETERMINED BY HISTOLOGICAL AND OTHER OBJECTIVE TECHNIQUES. H. P. Fleming, T. N. Blumer and H. B. Craig, *North Carolina State College.*

An objective method for estimating intramuscular fat in beef ribeye muscle was evaluated by obtaining measurements from 40 good and choice beef carcasses. The dimensions of visibly exposed fat deposits in cross sectional samples from the ribeye muscle were determined with the aid of a compass and a millimeter ruler. The data were tabulated as square millimeters of fat and number of deposits per square inch of ribeye. The average of the measurements from both sides of samples, one-half inch in thickness, was more closely related to ether extract values of the same sample (+.69) than were measurements from only one side (+.56). The data indicate the marbling variation that may be expected between samples. Measurements of the same sample which were determined, independently, by two persons were closely related (+.80). Standard errors for these measurements were computed. It was concluded that measurement of intramuscular fat will serve as a rapid and fairly accurate means of estimating the total fat within cross sectional samples of beef ribeye muscle. The method also affords a means of recording the manner of distribution of the fat which may be useful in further quality evaluation studies. In addition, ribeye areas devoid of visible marbling were studied in histological section to determine the manner of distribution of microscopic fat deposits. The area of fat and number of deposits were determined on a per-square-inch-of-tissue basis. There was a correlation coefficient of +.62 between the number of microscopic and macroscopic fat deposits of the ribeye sample.

48. A MOTORIZED FOOD GRINDER-RECORDING AMMETER TECHNIQUE IN DETERMINING BEEF TENDERNESS. J. A. Emerson and A. Z. Palmer, *Florida Agricultural Experiment Station.*

The tenderness of aged and unaged short-loin steaks and rib roasts from 44 carcasses was determined by the use of a food grinder, by taste panel and by the Warner-Bratzler Shear technique. The grinder apparatus consisted of a household food grinder wired in series with a strip-chart recording ammeter. A constant input of 120 volts A.C. was assured by the use of a voltmeter and a transformer between the grinder and power source. The number of joules of energy per gram of sample required in grinding was used as tenderness values. The accuracy of the food grinder method was determined by correlating the energy required in grinding with taste panel and shear values. Correlation coefficients between the food grinder values, and taste panel and shear values were highly significant.

49. SHRINKAGE AND KEEPING QUALITY OF DRY-CURED HAMS FROM HOGS OF DIFFERENT DEGREES OF FATNESS. James D. Kemp, James L. Goodlett and W. Y. Varney, *University of Kentucky.*

Hams from 142 Hampshire hogs of similar size, breeding and previous treatment were dry-cured, smoked and aged for 6 months at 65° F. and a relative humidity

of 55%. They were divided into four groups according to average backfat thickness as follows: 4.5 cm. or above; 4.0 to 4.4 cm., 3.5 to 3.9 cm. and under 3.5. After 6 months aging the average percent shrinkage for each group was 28.9, 29.7, 29.8, and 29.9, respectively, indicating a trend but not significant difference due to fatness. Free fatty acid values of the outside fat increased similarly with aging in all groups and averaged 11.09, 9.76, 10.88, and 12.04, respectively, for the four groups during aging. Peroxide values were similar in all groups. Average internal iodine values for each group tended to increase as backfat decreased although all were considered hard, as follows, 57.37, 57.40, 58.65, 59.61. These data indicate that within the range of fatness included and with hams from hogs of similar genetic and feeding background there are only minor differences in shrinkage and chemical change in ham fat during aging.

50. A STUDY OF THE VARIATIONS OF MYOGLOBIN CONCENTRATION IN "TWO-TONED" HAMS. George D. Wilson, Irene D. Ginger, B. S. Schweigert and W. J. Aunan, *American Meat Institute Foundation and University of Minnesota.*

Studies of the effect of antibiotic supplementation of hog rations at the University of Minnesota provided ham samples for a study of the effect of such supplementation on meat color. The degree of two-toning in the hams was of particular interest. Full sibs were allocated to the control and experimental rations and fed to market weight. The myoglobin content of selected light and dark muscles from the hams of 64 hogs was determined. The average myoglobin content of the dark muscles removed in the area of the femur was 1.28 mg. per gram of tissue and of the semitendinosus, 0.82 mg. per gram. These differences were not related to antibiotic supplementation but appeared to be related to genetic factors. Hams from Poland China hogs had the most extensive two-toning and those from the Chester White the least, while those from Duroc hogs were intermediate in this respect. The myoglobin analyses further indicated that two-toning was present when some muscles were darker than normal rather than when some muscles were lighter than normal. The paired ham from each hog which was cured showed the same but less marked differences in pigmentation.

51. EFFECTS OF SMOKING AND SMOKING TEMPERATURES ON THE KEEPING QUALITY, RANCIDITY DEVELOPMENT, AND PALATABILITY OF DRY-CURED HAMS. James L. Goodlett, James D. Kemp and W. Y. Varney, *University of Kentucky.*

Sixty hams were dry-cured for 21 days at 36° to 40° F. The hams were assigned to six groups each of 10 hams. Group I was not smoked, whereas groups 2, 3, 4, 5 and 6 were smoked to internal temperatures of 80°, 90°, 100°, 110°, and 120° F., respectively. All hams were aged for 6 months at 65° F. and a relative humidity of 55%. The hams were weighed at various intervals during processing and aging. Fat characteristics of the external ham fat were determined by iodine numbers, peroxide values, and free fatty acid content during processing and aging. After 6 months aging free fatty acid content was determined for seam fat of all hams. Two one-half-inch ham slices were used for palatibility tests and a third slice was used for salt analysis. Shrinkage increased throughout the processing and aging period, the greatest shrink occurring during the first month of aging ($P<0.01$). Hams smoked at 120° F. showed the highest shrinkage percentage. Iodine numbers and peroxide values increased during aging ($P<0.01$). Peroxide values were significantly higher in the no smoke group than in the smoked groups. Free fatty acid content increased during processing and aging ($P<0.01$). External fat showed a higher free fatty acid content than the seam fat. There were no significant differences in flavor or saltiness among groups, but hams smoked at 120° F. were judged the most tender. The hams smoked at 120° F. had a light red color and developed green spots during aging

52. SOME OBSERVATIONS ON THE USE OF ULTRASONIC MEASUREMENTS FOR DETERMINING FATNESS AND LEANNESS IN LIVE ANIMALS. J. F. Price, H. B. Pfost, A. M. Pearson and C. W. Hall, *Michigan State University*.

The depth of subcutaneous fat and the depth of the lean muscles along the top of the back have been determined with the Sperry Reflectoscope on a limited number of live hogs and cattle. To date, results with hogs have indicated that fatness can be accurately measured with ultrasonic equipment, as shown by a close relationship with live probe, carcass probe, backfat thickness on the intact carcass and backfat thickness measured on a cross section of the rough loin at the site of the ultrasonic reading. Similarly, results with swine have indicated ultrasonics can be used to measure the depth of lean. More difficulty has been encountered in interpretation of the readings at the shoulder than in interpretation of those taken at the loin or in the middle of the back. Work with beef cattle has indicated some promise for measuring fat thickness, although the relationship has been lower for cattle than for swine. As yet, results of the ultrasonic method of measuring depth of lean in cattle have not been promising.

53. CHLORPROMAZINE RESIDUES IN BEEF TISSUES. R. L. Henrickson, G. V. Odell, W. J. Costello and H. W. Reuber, *Oklahoma State University*.

Evidence is presented on the fate of chlorpromazine and its metabolite chlorpromazine sulfoxide in the bovine species. A dosage of 0.19 mg./lb. live weight was not sufficient to produce tranquility. Intravenous injections of 0.25 mg./lb. were sufficiently large to visibly depress docile animals. For easily excited animals (range stock), a dosage of 0.4 mg./lb. was required. Approximately 10 to 15% of the injected dose was excreted in the urine during the first 24-hour period following injection. The urine contained hemoglobin indicating evidence of red blood cell hemolysis. Tissue damage at the site of intramuscular injections was also considered to be an undesirable side effect. Small quantities of residual chlorpromazine were found in the fat, brain, heart, lung and kidney of those animals receiving 0.4 mg./lb. body weight when slaughtered 8 hours after injection. Animals held for 72 hours had no residual compound in any of the tissues. No residual form of the drug was found in any of the lean tissues, regardless of dose level. When chlorpromazine was purposely introduced into the muscle, it was bound in the tissue. Once in this form it was not lost during the normal cooler holding period.

54. A COMPARISON OF CERTAIN PHYSICAL AND CHEMICAL CHARACTERISTICS OF EIGHT PORK MUSCLES. E. J. Briskey, W. G. Hoekstra, R. W. Bray and R. H. Grummer, *University of Wisconsin*.

Samples of the following ham muscles—gluteus medius, biceps femoris, rectus femoris and gluteus accessorius were removed from 40 pork carcasses (135–160 lb.) at two intervals (2 minutes after slaughter and after 24-hour chill). Chilled samples of the longissimus dorsi (loin), serratus ventralis (Boston-butt), terres major (picnic shoulder) and pectoralis profundus (belly) were also removed for analysis. The following chemical and physical characteristics were determined for each muscle: pH, myoglobin, glycogen (four muscles), expressible water, fat, total moisture and color score of the gluteus medius only. The chilled muscle pH varied widely among muscles of each individual carcass (5.60 for the longissimus dorsi to 6.05 for the gluteus accessorius). The expressible water of the chilled samples also varied widely among the muscles, the greater values being associated with the lower pH values. Significant negative correlations were found between the chilled color scores and the fresh glycogen concentrations of the gluteus medius and the biceps femoris. Conversely, positive significant correlations were demonstrated between chilled color score and pH for all

chilled muscles except the pectoralis profundus and the gluteus accessorius. These data indicate that the chemical and physical characteristics of several of the muscles studied were highly related within individual carcasses, and that fresh glycogen, pH, expressible water, and color score were highly interrelated.

55. PHYSICAL, CHEMICAL, AND ORGANOLEPTIC RELATIONSHIPS IN FRESH PORK. M. D. Judge, V. R. Cahill, L. E. Kunkle and F. E. Deatherage, *The Ohio State University*.

Fifty-four pork loins were classified on the bases of the color, marbling, and firmness of the *Longissimus dorsi* muscle. Determinations were made of the fat and moisture content, water holding capacity, and pH value of each muscle sample. A six-member laboratory taste panel scored the tenderness, juiciness, and flavor of broiled chops. Color intensity was positively related to both water holding capacity and pH ($P<.01$). The degree of marbling was directly associated with percent chemical fat ($P<.01$) and water holding capacity ($P<.05$) and was inversely related to moisture content ($P<.01$). The degree of muscle firmness was correlated directly with water holding capacity, percent fat, and pH ($P<.01$). The correlation coefficients calculated between water holding capacity and pH (.62) and between moisture content and fat content (−.84) were highly significant. Tenderness was scored more accurately than the other palatability factors. Muscle color and firmness were related by simple correlation to tenderness at the 5 and 1 percent levels respectively; dark, firm tissue was less tender than light, soft muscle. Marbling was unrelated to tenderness but was associated with juiciness ($P<.01$). When all factors related to tenderness were considered independently of each other (multiple regression), two of these, namely firmness and pH, were found to be negatively related to tenderness at the 5 and 1 percent levels, respectively. A regression equation for the prediction of tenderness was developed.

56. CONNECTIVE TISSUE RELATION BETWEEN TOTAL HYDROXYPROLINE AND TENDERNESS OF BOVINE MUSCLE. E. Jean Loyd and Richard L. Hiner, *Agricultural Research Service, Beltsville, Md.*

Meat analysts have questioned the importance of connective tissue in the tenderness of meats because they have not been able to show its correlation with tenderness scores by accurate, precise data. Hydrolysis of the connective tissue usually discarded with the fat gives a higher total hydroxyproline content than previously reported in beef muscle and makes possible the significant correlation of hydroxyproline with tenderness scores. Hydroxyproline content of 26 beef muscles ranged from 0.016% of the most tender muscle to 0.160% of the toughest muscle. A method that separates connective tissue into three hydroxyproline-bearing fractions shows significant correlation between the total hydroxyproline content of nine beef muscles and two measurements of their tenderness. A short method of analysis, that halves the time required for the fractional procedure, shows significant correlation between total hydroxyproline content of six beef muscles and two measurements of their tenderness. Fourteen sets of duplicates analyzed by the short method show an average deviation from the mean of only $\pm 3.72\%$. Contrary to existing belief, the results of this study indicate that veal muscle contains less hydroxyproline than beef and that the amount of hydroxyproline increases somewhat in older animals.

57. THE MUSCLE-BONE RELATIONSHIP IN BEEF. L. E. Orme, A. M. Pearson, L. J. Bratzler, W. T. Magee and A. C. Wheeler, *Michigan State University*.

The objective of this study was to investigate the possible relationship existing between degree of muscling and various bone measurements of beef steers. Weights and several linear measurements were taken from each cleaned metacarpal and metatarsal while various linear measurements of both the transverse and vertical

processes of the first four lumbar vertebrae were derived from radiographs. The fore and hind cannons were weighed to the nearest gram while all subsequent linear measurements were taken in millimeters. Eye muscle area was used as the index of muscling. Simple correlation coefficients of rib-eye area with the various weights and measurements of the cannon bones were not statistically significant. However, when live animal weight was standardized, the standard partial regression coefficients of rib-eye area on weight, length, width and circumference of either the hind or fore cannons ranged from —.18 to —.50. Correlation coefficients of radiographic measurements of the vertical and transverse processes were .45 and .47 for rib-eye area with body width of the vertical processes and the width of the lumbar vertebrae, respectively. Multiple correlation coefficients of rib-eye area with live weight and width of the transverse, width of vertical processes, width of the vertebrae body and the length of the anterior articular processes were .58, .60, .58 and .57, respectively. Results indicate that radiographic measurements of the lumbar vertebrae were more closely related to rib-eye area than either fore or hind cannon bone measurements.

58. LIMITED vs. FULL FEEDING AS RELATED TO CARCASS COMPONENTS WITH PARTICULAR REFERENCE TO MEAT PRODUCTION. E. S. E. Hafez, R. E. Mauer and M. E. Ensminger, *State College of Washington.*

Palouse gilts were divided into two groups; one group was full fed from weaning to 150 lb.; the other group was fed 70% as much as the full fed pigs. After six generations, one-half of the pigs in each group were shifted to the other plane of nutrition, thus forming four groups; high-high (HH), low-high (LH), low-low (LL) and high-low (HL). Nineteen F_{10} gilts were slaughtered at comparable ages. Half the carcasses were completely dissected to lean, fat, bone and skin and remaining halves were broken down into standard primal cuts. The feeding level in the first six generations had no after-effect on proportion of tissues and primal cuts in carcass; or distribution of lean, subcutaneous fat and inter-muscular fat within cuts. The average dressing percentage in the feeding groups was 77.41, 76.10, 72.52 and 72.22, respectively. Total lean in carcass averaged 53% in limited fed and 41% in full fed; carcass body fat (excluding leaf) averaged 29% in limited fed and 41% in full fed; carcass bone averaged 8.5% in limited fed and 7% in full fed; these differences were significant at 1% level. Bone in the loin cut averaged 27% in limited fed and 31% in full fed. The percentage of bone in other cuts was not affected by feeding. Intestinal fat to total carcass fat was 6.6% in limited fed and 4.4% in full fed. The percentage of trimmed Boston butt, loin and ham was higher in limited fed than in full fed groups.

59. CORRELATION BETWEEN LIVE HOG SCORES AND CARCASS MEASUREMENTS. H. J. Tuma, R. A. Merkel and D. L. Mackintosh, *Kansas State College.*

Thirty-nine barrows were appraised by three staff members, a graduate student from Kansas State College and two prominent commercial hog breeders, to determine the accuracy with which individuals can estimate certain carcass characteristics. The information requested was as follows: estimate of average backfat thickness, carcass length, percent lean cuts and live grade. These characteristics seem to be associated with the cut-out value of the market hog and accurate live appraisal would facilitate marketing under the merit buying system. The correlation coefficients for the estimated compared to the actual backfat thickness and carcass length varied from 0.36 to 0.73 and 0.37 to 0.82, respectively. These correlations were either significant or highly significant for all scorers. Estimation of percent lean cuts was not significantly correlated for any scorer. The range was 0.07 to 0.25, two individuals approaching statistical significance. The scorers correctly estimated live grade for approximately 65% of the hogs. The range for all scorers was 61.5 to 69.2%, which was higher than any other characteristic. There was a tendency for all scorers to under-

estimate rather than overestimate those traits not scored correctly. Correlation coefficient between percent lean cuts and the following characteristics are: Live probe, —.66; grade, —.60; average fatback thickness, —.51; lumbar lean, 0.29; and carcass length, 0.28. Correlations between average backfat thickness and lumbar lean were not significant, 0.11. Live probe and backfat thickness were highly significantly correlated, 0.84.

60. USE OF ANTIOXIDANTS IN LARD AND DRY-CURED BACON. Herbert W. Ockerman and James D. Kemp, *University of Kentucky.*

Five commercial antioxidants were added to lard and dry-cured bacon. Propyl gallate, butylated hydroxytoluene and butylated hydroxyanisole were incorporated into lard at a concentration of 0.01% and into bacon at a concentration of 0.02% of the fat content. Tenox II and Sta-sweet were added to lard in the amount of 0.02% and into bacon at 0.04% of the fat content. The lard was stored at 38°, 65° and 95° F. and sampled after 2 and 4 months. Chemical determinations were made for iodine, peroxide and free fatty acid values. The bacons were stored at 65° F. (relative humidity of 55%) and were sampled after 2 and 4 months. Chemical determinations were made for peroxide and free fatty acid values and the bacon was evaluated by an organoleptic taste panel. The chemical tests for lard indicated that all antioxidants gave a highly significant increase in lard stability and all gave significantly lower peroxide values to the bacon. Propyl gallate reacted with traces of iron, resulting in discolored products. The taste panel rated the bacons treated with Tenox II, Sta-sweet, BHA and propyl gallate as significantly better in relation to rancidity.

61. BREED AND CROSSBREED LAMBS FOR PRODUCTION OF LIGHT-WEIGHT CARCASSES. W. W. Heinemann, J. H. Shropshire and M. E. Ensminger, *State College of Washington.*

Columbia, Hampshire and Southdown ewes were used to produce purebred lambs and Columbia and Hampshire ewes were bred to Southdown rams to produce crossbred lambs. Approximately half of the lambs were slaughtered near 75 lb. and the remainder at about 90 lb. Data will have been obtained on about 400 lambs over a two-year period at the conclusion of the 1958 season. Differences in carcass quality and other measurements in 1957 due to parentage were small (excluding Southdown lambs). Increased weight at slaughter was responsible for somewhat better finished carcass. However, 78.3% of the light lambs graded Choice, the remainder, Good. The 90-lb. lambs yielded 8.3% Prime carcasses, 84.4% Choice and 7.3% Good. Dressing percentage was not affected by live weight. Likewise, rate of gain was not affected by weight at slaughter but slight breed differences were shown. Some differences due to breed and weight at slaughter appear to exist. The light carcasses sold at the same prices (within grade) as the heavier carcasses, indicating good consumer acceptance of lighter lamb cuts.

62. FACTORS AFFECTING THE VISCERA WEIGHTS OF HOGS. C. B. Ramsey and James D. Kemp, *University of Kentucky.*

Average weights of viscera and their contents of 283 Hampshire hogs, weighing from 180 to 215 lb., decreased 4.04 lb. during the years 1952 through 1957. All hogs received similar treatment and rations except the dietary crude protein level was reduced from 20–18–16% to 16–14–12% in the fall of 1954. Statistical analyses were performed to discover the cause of this decrease in viscera weights. Significant differences existed between the two protein levels ($P<.01$) and among sire progeny groups within years ($P<.05$). Years within protein levels and barrows and gilts did not

differ significantly. Fall-farrowed pigs had lighter viscera weights than spring-farrowed pigs ($P<.01$). Simple correlation coefficients were calculated between viscera weights as a percentage of warm dressed weight and six other factors. They were live weight (.28), average backfat thickness (.04), carcass length (.03), warm dressed weight (.37), and average temperature for 30 days (.11) and 60 days (.13) prior to slaughter. Coefficients for live weight, warm dressed weight, and average temperature for 60 days prior to slaughter were statistically significant; that for average temperature for 30 days prior to slaughter approached significance.

63. EFFECT OF SEVERAL FEEDING PROGRAMS AND ARSONIC COMPOUNDS ON BACKFAT THICKNESS OF SWINE. M. J. Brinegar, E. C. Hornback and J. E. Hunter, *Allied Mills, Inc., Libertyville, Illinois.*

Litters were divided and regrouped at farrowing for comparison of 3- and 8-week weanings. The pigs weaned at 3 and 8 weeks weighed 51.6 and 44.1 lb. respectively, and were 9½ weeks old at the start of these experiments. Backfat measurements (live probes) were made when the average weights of the various groups were 190 to 200 lb. Backfat measurements (figures in parentheses represent the number of hogs in each observation) for the hogs which had been weaned at 3 and 8 weeks were 1.40 in. (122) and 1.38 in. (133), respectively. In one series of comparisons, backfat thickness for the controls was 1.33 in. (44), for those receiving 0.0025% 3-nitro, 4-hydroxy phenylarsonic acid in their diet, 1.39 in. (41) and for those receiving 0.01% arsanilic acid, 1.42 in. (41). In another series of comparisons pigs were fed (A) complete mixed ration in meal form (corn and concentrate), (B) the same ration pelleted or (C) whole shelled corn fed free-choice with the concentrate pelleted. Backfat measurements for the three groups were (A) 1.41 in. (43), (B) 1.52 in. (43) and (C) 1.25 in. (43). The pigs fed free-choice consumed concentrate at a rate 54% higher than was included in the mixed rations. The protein levels in the mixed and free-choice rations as consumed after 100 lb. body weight were 11.8% and 15.6%. It was concluded that the significantly less backfat thickness in the pigs fed free-choice was primarily due to their higher protein consumption and in part to a 6.6% lower rate of gain.

64. RAISING DAIRY CALVES WITHOUT WHOLE MILK. J. M. Bell, *University of Saskatchewan, Canada.*

The results of feeding experiments involving over 150 Holstein-Friesian calves are reported. No whole or fresh skimmilk was fed following a two-day colostrum feeding period. Milk substitutes containing 40 to 50% dried skimmilk, 5 to 10% emulsified, stabilized lard, at least 30 p.p.m. of Aureomycin or Terramycin, oat flour, brewer's dried yeast, $FeSO_4$, riboflavin and vitamins A and D permitted gains equal to, or exceeding, the Beltsville standards. Supplementary lecithin was of no value. Weaning calves according to weights rather than ages proved better, apparently because of differences in physiological development existing among calves during the first two or three months of life.

65. FACTORS CONTRIBUTING TO WITHIN TREATMENT VARIABILITY IN BABY PIG NUTRITION EXPERIMENTS. V. W. Hays, D. L. Frape, P. G. Homeyer, V. C. Speer and D. V. Catron, *Iowa State College.*

Summaries of 51 baby pig experiments involving 4819 pigs showed average coefficients of variation of 13.7% for gains and 8.8% for feed required per pound of gain. These values were based on calculations using the pen of three to five (av. of four) pigs as the experimental observation. These experiments were primarily of randomized block design in which the pigs were allotted by initial weight outcome groups with varying degrees of control on litter mates across treatments. Further studies on the factors contributing to this variability indicate that greater precision may be obtained

by placing more emphasis on the genetics of the pig (both dam and sire) and less on factors such as initial weight and age which may be used as co-variables in the analysis of the data. Average litter gain and initial weight are more highly correlated with individual pig gain than initial age within the restricted limits of the experiments studied. Data were obtained on the effect of other pigs in the pen on individual performance.

66. NUTRITIONAL STUDIES WITH GIBBERELLIN IN SWINE RATIONS. W. C. Sherman, N. D. Magruder, W. M. Reynolds and H. G. Luther, *Chas. Pfizer & Co., Inc., Terre Haute, Indiana.*

Two replicated experiments with 112 early-weaned pigs (7–10 days old) were conducted to determine effect on growth of gibberellin in prestarter-starter type rations. Basal rations fed for 42 days contained yellow corn meal, soybean oil meal, dried skim milk, stabilized animal fat, sucrose or cerelose, minerals, vitamins and oxytetracycline. In one experiment, treatments consisted of crystalline gibberellin at levels of 0, 10, 100 and 1000 mg. per ton of feed. Average daily gains (lb.) and feed efficiency (lb. feed per lb. gain) were respectively 0.51, 2.17; 0.60, 1.98; 0.54, 2.01; and 0.62, 1.96. The average daily gains of the groups which received the gibberellin at levels of 10 mg. and 1000 mg. per ton were significantly greater than the controls ($P<.05$). In a second trial with the same levels of gibberellin, average daily gains and feed efficiency were, respectively, 0.64, 1.91; 0.70, 1.90; 0.69, 1.88 and 0.65, 2.00. There were no differences in the appearance or behavior of the animals attributable to the treatments. The data indicate that gibberellin is not toxic to pigs when fed at levels up to 1 gm. per ton and may improve performance.

67. CREATINE IN THE DIET OF THE BABY PIG. E. R. Miller, D. A. Schmidt, D. E. Ullrey, J. A. Hoefer and R. W. Luecke, *Michigan State University.*

Two trials were conducted to determine if the addition of 0.2% creatine monohydrate or an equivalent amount of L-arginine hydrochloride and glycine to a synthetic milk diet for the baby pig will improve his rate of body growth, food utilization, and size and creatine content of muscle. The feeding of creatine resulted in a 14% increase in rate of gain and an 8% increase in efficiency of food utilization over the control group in one of the trials. The size and creatine content of the right hind superficial digital flexor and gastrocnemius muscles of pigs receiving dietary creatine were increased over pigs from the control groups in both trials. The data from both trials indicate no advantage of supplying additional arginine and glycine to the diet and data from metabolism studies demonstrate that this additional arginine and glycine was not converted into creatine by the pig. The feeding of these additives did not significantly affect the hematology or the size of the critical organs of the pigs.

68. EFFECT OF PROTEIN LEVEL ON THE LYSINE REQUIREMENT OF WEANLING PIGS. R. E. Chance, A. F. O. Germann II, W. M. Beeson and E. T. Mertz, *Purdue University Agricultural Experiment Station.*

Two factorial experiments were conducted with 0.5, 0.7 and 0.9% lysine at 10, 15 and 20% protein levels. Lysine and protein levels quoted were calculated on a moisture-free basis. Weanling pigs, 7 weeks of age and averaging 25 lb., were used in 28-day trials with three and four pigs per treatment in experiments 1 and 2, respectively. Basal ration contained corn gluten feed, corn gluten meal and whole corn germ as protein sources in the first experiment and corn and soy protein in the second. Crystalline amino acids supplemented the 10% protein rations to give the essential minimum requirement pattern for swine. N-containing feeds and amino acid supplements fed at the 10% protein level were increased 1.5 and 2 times, respectively, for the 15 and 20% protein diets. All diets were essentially iso-caloric. Av. daily gains

and feed efficiencies at the 10, 15 and 20% protein levels, respectively, in experiment I were (0.5% lys.): 0.55, 3.65; 0.62, 3.43; 0.49, 3.16; (0.7% lys.): 0.74, 2.95; 0.89, 2.60; 0.88, 2.67; (0.9% lys.): 0.87, 2.83; 0.86, 2.39; 1.04, 2.16; and in experiment II were (0.5% lys.): 0.84, 2.88; 0.60, 2.92; .46, 3.14; (0.7% lys.): 1.24, 2.33; 1.04, 2.15; 0.73, 2.43; (0.9% lys.): 1.22, 2.38; 0.96, 2.11; 0.96, 2.17. The lysine requirement was not influenced by protein level in experiment I, being near 0.9%, but increased from 0.7% at 10 and 15% protein levels to 0.9% at 20% protein in experiment II. Protein efficiency improved as lysine was increased in experiment I but leveled off at 0.7% in experiment II and decreased as the protein level increased in both trials. Feed consumption was not affected by protein level in experiment I but decreased as the protein level increased in experiment II.

69. LYSINE SUPPLEMENTATION FOR BARLEY RATIONS. W. E. Dinusson, Duane Erickson and Donald W. Bolin, *North Dakota Agricultural College.*

Six experiments involving 76 pigs were used to study the effect of lysine supplementation to a barley ration. In five trials a modified paired-feeding design where pigs were paired within litters was used. In each of the first four trials eight litter mates had an average initial weight of 25 lb. In experiment 1, the pigs that received the 13.8% basal protein ration plus 0.8% DL-lysine gained 40% faster ($P<0.05$) on 28% less feed than those fed the basal ration. In experiment 2, the pigs receiving the same basal ration plus 0.2% DL-lysine gained 11% faster. The pigs in trials 3 and 4 were fed a basal barley ration with no additional protein. Those receiving the 0.4% DL-lysine gained 62% faster and ate 22% less feed ($P<0.01$). In the fifth trial, 6 pairs of pigs were fed a basal barley (13.8% protein) ration. The pigs which had 0.2% DL-lysine added to the basal ration gained 15% faster ($P<0.05$) on 13% less feed per lb. gain ($P<0.01$). Experiment 6 (six pigs per lot, eight lots) was continued until the pigs averaged 200 lb. Two 13.8% protein basal barley rations (meat scraps, and blood meal; meat and fish meal) with and without 0.2% DL-lysine resulted in 9% increase ($P<0.05$) for the lysine. There was no difference in final feed conversion; however, large differences were noted before the pigs reached 100 lb. The addition of lysine, at all levels studied and in all trials, gave beneficial results as measured by average daily gain and feed efficiency.

70. TASTE PREFERENCES OF CATTLE. O. J. Stubbs and M. R. Kare, *New York State Veterinary College.*

An experimental method for studying taste preferences of cattle was developed. It was employed in evaluating the response of the bovine to taste stimulants in the four categories, sweet, sour, bitter, and salty, usually recognized by man. Dairy calves were offered a choice between distilled water and "flavored" distilled water. The design was such that theoretically the calves would approach each of the choices an equal number of times. Under the conditions of these experiments the calves exhibited preference for dilute sucrose solution and various degrees of rejection for dilute hydrochloric acid, sodium chloride, and quinine sulfate solution. The results of subsequent studies employing a wide variety of artificial sweeteners and a group of other sugars differ from that with sucrose. This suggested that the taste reaction of the cow is probably physiologically different from our own. A conclusion that the cow has a sense of taste in some aspects different from our own but relatively acute was warranted.

71. THE EFFECT OF FEEDING A MOLASSES-UREA-ALCOHOL SUPPLEMENT TO FATTENING LAMBS. R. M. Jordan and H. E. Hanke, *University of Minnesota.*

Two trials were conducted to study the value of a molasses-urea-alcohol supplement (Morea) as a substitute for "conventional" protein supplements for fattening

lambs. In the first trial lambs were full-fed a shelled corn and brome hay ration. In addition Lot 1 received liquid molasses free-choice and 0.30 lb. of soybean oil meal per lamb daily. Lot 2, received Morea free choice. In Trial II all the lambs were full-fed a standard shelled corn and alfalfa hay ration. In addition Lot 1 received 0.10 lb. of soybean oil meal; Lot 2 received 0.10 lb. soybean and was offered 0.50 lb. of liquid molasses. Lot 3 was offered 0.50 lb. of Morea. In Trial I lambs fed the basal ration plus soybean oil meal and molasses gained 0.51 lb. per lamb daily. Lambs fed Morea as the major source of protein gained 0.44 lb. per lamb daily. Lambs in Lot 1 ate 1.14 lb. of molasses per lamb daily as compared to 0.81 lb. of Morea consumed per lamb daily in Lot 2. In Trial II, Lot 1 gain 0.52 lb.; Lot 2, 0.43 lb. and Lot 3, 0.40 lb. per lamb daily (Lot 1 gain significantly faster, $P<0.01$, than either Lot 2 or 3). Lot 3 consumed only 0.35 lb. of Morea per lamb daily, whereas Lot 2 consumed 0.48 lb. of molasses per lamb daily. Carcass grade and yield were not affected by treatment in either trial.

72. BENEFICIAL INFLUENCES OF METHIMAZOLE IN FATTENING CATTLE RATIONS. Wise Burroughs, Edmund Cheng, Arthur Raun, C. C. Culbertson and E. A. Kline, *Iowa State College.*

Three experiments involving 30 lots of cattle were conducted in which different amounts of methimazole (Tapazole) were fed in fattening rations for varying lengths of time. Following the feeding periods, all lots of cattle were submitted to carcass evaluation including Federal grade, dressing percent, loin depth of external fat and area of the *longissimus dorsi* muscle. Several of the lots were subjected to more detailed carcass evaluation which included physical separation of fat, lean and bone of a 3-rib section from each carcass as well as ether extracts and dry matter determination of the *longissimus dorsi* muscle. Rate of liveweight gain was consistently increased by feeding levels of 300 to 600 mg. of Tapazole per animal daily. The greatest increase occurred during the first month of feeding in each trial. Feed consumption per animal per day tended to decrease slightly especially with the longer feeding periods and with the higher levels of Tapazole fed. Feed required per unit liveweight gain was consistently improved. Beef carcass grade tended to be increased by Tapazole feeding of several months duration but not short feeding periods of less than 3 months. In the longer feeding periods, separable fat, depth of fat over the loin and percentage of fat in the *longissimus dorsi* muscle were increased by Tapazole feeding.

73. COMPLETE MIXED PELLETED RATIONS FOR SUCKLING LAMBS. T. W. Perry, W. M. Beeson and Claude Harper, *Purdue University Agricultural Experiment Station.*

Previous research has indicated the value of creep rations for suckling lambs in drylot. Subsequent research has been conducted to identify the component nutrients and feedstuffs, and combinations thereof, essential for optimum growth of suckling lambs. In past research, a pellet containing 10% sugar, B-vitamins and trace minerals, in addition to a control ration of corn, soybean meal, minerals and vitamins A and D, has given maximum growth response. When each of the listed additives was fed separately, along with the control ration, the following weight (May 7), daily gain and daily feed consumption figures were obtained: Control ration, 58.5, 0.61, 0.80; 10% sugar, 59.0, 0.60, 0.78; B-vitamins, 58.3, 0.58, 0.79; trace minerals, 56.1, 0.57, 0.82; 10% sugar, B-vitamins and trace minerals, 63.6, 0.68, 0.96. At the time of pasture season (May 7) the lambs were weighed and all weighing 70 lb. or more were weaned for fattening. The remaining lambs were regrouped into three groups. The treatments and daily gain are indicated as follows: Lot I, on pasture with mothers, pelleted creep ration available, 0.50 lb. per day; Lot II, on pasture with mothers, no creep ration available, 0.36 lb. per day; Lot III, weaned, fed out in drylot, 0.52 lb. per day.

74. COMPARISON OF LONG HAY, LARGE SIZE PELLETS AND FIELD BALED LEGUME HAY FOR DAIRY COWS. A. N. Bringe, R. P. Niedermeier, H. J. Larsen, and H. Bruhn, *University of Wisconsin.*

Two 6-week single reversal feeding trials were run to compare pelleted and field baled long hay. Hay pellets were 4 in. in diameter and had a pellet density of 25 to 30 lb. per cu. ft. Hay for the first trial was second cutting alfalfa and grass hay barn-dried with heat. In the second trial first cutting field cured alfalfa hay was fed. Four pairs of Holstein cows were used in the first trial and three pairs in the second. All cows were past the peak of their lactation curve. Daily individual milk production and feed consumption records were kept. Concentrates were fed at the rate of 1 lb. per 3.2 lb. of 4% FCM in the first trial and 1 lb. per 4.2 lb. of 4% FCM in the second trial. Hay was the only roughage and was fed in excess twice daily. Pelleted hay was eaten at the rate of 2.52 lb. per 100 lb. body weight as compared to 2.41 lb. per 100 lb. body weight for non-pelleted hay in the first trial and correspondingly at the rate of 2.39 and 2.40 in the second trial. Hay intake is expressed on a 100% D.M. basis. Daily 4% average milk production was 42.4 lb. on pelleted as compared to 40.9 lb. on non-pelleted in the first trial and 36.5 and 36.2 lb. in the second. Analysis of variance of data showed no significant differences at the 5% level between pelleted and non-pelleted long hay in regard to intake, milk production or body weight. Cows ate the pelleted hay without difficulty or apparent ill effects.

75. PELLETED RATIONS FOR FATTENING BEEF CATTLE. Conrad J. Kercher and N. W. Hilston, *University of Wyoming.*

Fifty-six yearling Hereford steers which averaged 864 lb. were randomly divided into eight lots. Two lots were randomly assigned to each of the treatments which consisted of the following proportions of suncured alfalfa and concentrates: (1) 50-50, non-pelleted (2) 50–50, pelleted (3) 70–30, pelleted (4) 70–20–10% tallow, pelleted. The pellets were 3/8" in diameter. Corn silage was fed to all groups at a constant rate. The balance of the ration was fed *ad libitum.* The average daily gains by treatment during the 114-day feedlot period were as follows: (1) 2.22 lb., (2) 2.92 lb., (3) 2.86 lb. and (4) 2.69 lb. Pelleting the hay and grain ration significantly increased the daily gain. The level of roughage in the pellet or the inclusion of animal tallow did not significantly influence feedlot gains. The pellet-fed steers consumed more feed per day (hay and grain), (1) 19.0 lb. (2) 25.0 lb. (3) 25.3 lb. and (4) 21.7 lb. There were no significant differences in the amount of feed required to put on 100 lb. of gain. The level of roughage in the pellet or the inclusion of animal tallow did not significantly affect the feed intake or feed efficiency. The feed costs per 100 lb. gain were as follows: (1) $15.39 (2) $20.19 (3) $19.96 and (4) $23.14. The average carcass yield and carcass score (lower score-higher carcass grade) for the steers were as follows: (1) 60.83%, 4.4; (2) 61.97%, 2.5; (3) 61.21%, 2.9; and (4) 62.50%, 2.4. There were no significant differences in the carcass yield or score.

76. THE INFLUENCE OF SEASON AND WEIGHT ON THE OPTIMUM CALORIE-PROTEIN RATIO FOR GROWING AND FINISHING SWINE. P. R. Noland and K. W. Scott, *University of Arkansas.*

A total of 126 cross bred weanling (40 lb.) pigs were self-fed corn-soybean meal rations of three different protein levels (12, 16 and 20%) at each of three energy levels (950, 1050, 1200 Calories of Productive Energy (Fraps) per lb.) to a final weight of 200 lb. Identical rations were fed during two seasons (winter and summer). Stabilized animal fat and ground rice hulls were used to adjust energy levels. Analysis of the gains to 75 lb. showed highly significant effects of season, protein level and protein x energy interaction and a significant effect of energy level. Most of the protein effect was linear. Pigs fed 1200 calorie rations gained faster ($P<.01$) than those

fed 1050 calorie rations. There was no difference between the gains of pigs fed 950 to 1050 calorie rations. From 75 to 125 lb. the protein effect was primarily cubic. The effect of energy on gains was significant. Feed efficiency was directly related to level of energy, but there was little effect of protein level on feed efficiency. Carcasses of representative slaughtered animals showed that pigs fed the highest energy rations had the longest and fattest carcasses. Highly inbred litter-mates were self fed the same rations in a 9 x 9 Latin square experiment. Response to level of protein was linear. There was no difference between the 950 and 1050 calorie levels, but a significant difference existed between the 1050 and 1200 calorie fed groups.

77. THE EFFECT OF THE CALORIE-PROTEIN RATIO ON DIGESTIBILTY, FEED EFFICIENCY, AND WEIGHT GAIN IN GROWING SWINE. R. S. Lowrey, W. G. Pond, and J. H. Maner, *Cornell University*.

Thirty Yorkshire and Berkshire pigs averaging 19.8 lb. were allotted to a 3 x 2 factorial experiment in which the variables were protein and fat. The animals were fed practical rations *ad libitum* on concrete for 35 days. Average daily gains and feed per lb. of gain were as follows: Lot 1 (13% protein—0% added fat), 1.07, 2.53; Lot 2 (13% protein—10% added fat), 0.83, 2.40; Lot 3 (16% protein—0% added fat), 1.02, 2.44; Lot 4 (16% protein—10% added fat), 0.99, 2.06; Lot 5 (19% protein—0% added fat), 1.02, 2.23; and Lot 6 (19% protein—10% added fat), 1.20, 191. Average daily protein intake for pigs in lots 1–6 were 0.36, 0.27, 0.40, 0.33, 0.45, 0.45 lb., respectively. Calculated digestible energy-protein ratios determined by using 4.5 Calories per gm. of TDN (Crampton *et al.*, 1957) for the six treatments were respectively, 28.3, 32.7, 22.7, 26.2, 18.8, and 21.8 Calories per percent protein. Chromium oxide digestibility determinations following a four-day collection period during the fifth week resulted in the following values for percent dry matter, ether extract, and protein digestibility, respectively, in the following lots: (1) 77.0, 33.4, 59.7; (2) 79.4, 78.7, 66.1; (3) 77.5, 39.8, 66.0; (4) 79.2, 80.4, 71.2; (5) 79.9, 38.2, 74.6; and (6) 79.9, 81.7, 75.9. Differences in dry-matter digestibility were insignificant; however, differences in fat and protein digestibility were highly significant ($P<0.01$). Orthogonal comparisons of the data for protein digestibility showed that the protein component was highly significant ($P<0.01$) while the fat component was significant ($P<0.05$) thus denoting increased digestibility of protein by addition of fat.

78. THE PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING-FATTENING SWINE AS AFFECTED BY RATION LEVELS OF PROTEIN AND INEDIBLE FATS. D. M. Baird, H. C. McCampbell and W. E. Neville, Jr., *Georgia Experiment Station*.

Feeding tests were conducted to determine the relationship between levels of protein and tallow on performance and carcass characteristics of growing-fattening hogs. Six lots of eight pigs each were fed in drylot from approx. 40 to 200 lb. Animals were alloted according to weight, sex, litter and sire. They were removed individually and slaughtered at market weight. Carcass observations were made and fat samples collected for refractive index measure. Two levels of protein were fed, low protein (LP) and high protein (HP) to each of three lots. Treatments and levels of added tallow were (1) LP—0% tallow, (2) LP—5% tallow (3) LP—10% tallow, (4) HP—0% tallow, (5) HP—5% tallow and (6) HP—10% tallow. Low levels of protein were 15, 13 and 11% and high levels were 21, 19 and 17% with reductions in levels made at 80 and 125 lb. The average therms per cwt. of feed was 77, 87, 98, 76, 87 and 103 for each of the six respective rations. The ADG and feed efficiency were (1) 1.48, 365 (2) 1.43, 363 (3) 1.52, 347 (4) 1.40, 370 (5) 1.45, 363 and (6) 1.63, 314. Increasing the caloric density improved feed efficiency but had no significant effect on rate of gain. Including an additional 40 animals, from a similar test to be reported, significant negative correlations were obtained between

the calorie: protein ratio and ADG and between ADG and feed efficiency. Added tallow did not statistically increase depth of back fat. Also there was no treatment effect on carcass length or loin area. Refractive index values for both leaf and back fat differed significantly only between lots 1 and 6. Added tallow increased the cost of gain on low protein rations; however, costs were reduced by tallow additions to high protein rations.

79. EFFECT OF ADDING ANIMAL FAT TO SWINE RATIONS. M. H. Kennington, T. W. Perry and W. M. Beeson, *Purdue University Agricultural Experiment Station.*

In a series of three experiments 138 weanling pigs averaging 30.2 lb. were fed a practical swine growing ration containing from 14 to 20% protein with 0 to 20% added fat (stabilized lard) *ad libitum* to an average of 125 lb. Added levels of fat increased growth rate significantly. This effect was linear. Feed consumption, in general, decreased as the level of added fat was increased (5.09, 4.68, 4.42, and 4.03 lb. average daily feed consumption for 0, 10, 15 and 20% added fat, respectively). However, feed consumption was not reduced in Experiment I. Levels of fat greatly increased feed efficiency, up to 43.6% when 20% of fat was added (211 lb. of feed/100 lb. gain). This effect was linear. Added fat increased back-fat thickness (1.20, 1.36, 1.39 and 1.49 in. for 0, 10, 15, and 20% added fat, respectively). This effect was linear. Level of protein did not influence growth rate, feed consumption, feed efficiency or backfat thickness. Interaction (fat x protein) was not significant, indicating that in general the effect of fat was the same at all levels of protein fed. The range of Calorie/protein ratios used (88:1 to 150:1) did not effect any of the factors being evaluated. Although barrows gained faster than gilts, over-all reaction to treatments was similar.

80. THE EFFECT OF VARYING LEVELS OF FIBER OF DIFFERENT SOURCES UPON GROWTH AND CARCASS CHARACTERISTICS OF SWINE. L. N. Hochstetler, J. A. Hoefer, A. M. Pearson and R. W. Luecke, *Michigan State University.*

Twenty-seven pigs were used in each of four trials designed to study the effect of replacing part of a basal ration with different fibrous feeds. Data were obtained on feedlot performance and carcass traits. In the first trial, oats was used to replace 20 and 40% of the basal ration. There were no significant differences between treatments. In the second trial, wheat bran replaced 20 and 40% of the basal ration. There was a highly significant ($P<.01$) decrease in daily gain, and a significant ($P<.05$) decrease in backfat accompanied by an increase in feed per pound of gain, between the pigs receiving 40% wheat bran and those receiving the basal ration. In the third trial, alfalfa replaced 10 and 20% of the basal ration. The results exhibited non-significant trends similar to the second trial. Wheat bran was repeated in the fourth trial at the same levels as the second. In this trial, there was a significant ($P<.05$) decrease in rate of gain, backfat thickness, dressing percentage and a highly significant ($P<.01$) decrease in percent of fat trim and increase in feed per pound of gain between the pigs receiving the 40% wheat bran and those receiving the basal ration. The carcasses of the 40% lot exhibited a significant ($P<.05$) increase in both the percent of lean cuts and primal cuts (carcass basis) over both the basal and 20% wheat bran lots.

81. THE DETERMINATION OF THE PRODUCTIVE ENERGY VALUE OF FEEDS FOR THE WEANLING PIG. B. G. Diggs, D. E. Becker, A. H. Jensen and S. W. Terrill, *University of Illinois.*

It is necessary to determine energy gain of animals in order to determine productive energy of a ration. We have attempted to correlate specific gravity of the

live pig with its total energy value. Five weanling pigs were sacrificed by heart puncture and frozen at the beginning of the experiment. Twenty pigs were put on a five-week feeding experiment. At the end of this period, the pigs were anesthetized and specific gravity of each pig was determined by water displacement. Each pig was then sacrificed and frozen. The frozen pigs were ground and samples were taken for the following determinations; % fat, % water, energy value per gram of ether extract and energy value per gram of the fat-free, water-free sample. With this information, the energy value of the pig was calculated and the energy furnishd by the fat fraction and the nonfat fraction was determined. In this preliminary test the correlation between specific gravity of the live pig and percent fat was —.65. It is hoped the method for determining specific gravity can be improved so the fat content of a live pig can be calculated from its specific gravity. A correlation of —.94 was obtained between percent fat and percent water of the pigs. Therefore by knowing the percent fat one can determine the water and fat-free, water-free portion of a pig and by knowing the energy value of these fractions, the energy content of the live pig can be determined from its specific gravity. Thus, measuring the specific gravity of the live pig at the start and finish of a feeding period would provide a basis for determination of productive energy value of the ration.

82. EFFECTS OF VARIATIONS IN DIETARY ENERGY DENSITY ON THE B-VITAMIN REQUIREMENTS OF THE WEANLING PIG. R. F. Sewell and J. L. Carmon, *University of Georgia.*

A 2 x 4 factorial experiment employing eight groups each of five pigs with one replication was used to study the addition of B vitamins to swine rations at two levels of energy density. A corn-dehulled soybean oil meal basal ration was used which was fortified with calcium, phosphorus, trace mineralized salt and vitamins A and D. The ration treatments were as follows: (1) basal; (2) basal + pantothenic acid; (3) basal + B-vitamins (thiamine, pyridoxine, riboflavin, niacin, choline, and B_{12}); (4) basal + pantothenic acid + B-vitamins; (5) basal + 10% stabilized tallow; (6) basal + 10% tallow + pantothenic acid; (7) basal + 10% tallow + B-vitamins; and (8) basal + 10% tallow + pantothenic acid + B-vitamins. Average daily gains and lb. of feed per lb. of gain for the various treatments were as follows: (1) 1.55, 3.44; (2) 1.60, 3.32; (3) 1.64, 3.34; (4) 1.66, 3.43; (5) 1.71, 2.66; (6) 1.63, 2.86; (7) 1.86, 2.61; and (8) 1.83, 2.66. Supplementing the basal ration with either pantothenic acid, B-vitamins, or a combination of the two, increased gains. Supplementing the rations containing 10% tallow with the B-vitamins resulted in an increase in rate of gain whereas addition of pantothenic acid alone slightly depressed gains. There was a highly significant decrease in the amount of feed required to produce a lb. of gain when tallow was added to the ration. A highly significant tallow x B-vitamin interaction was found with regard to feed conversion.

83. INFLUENCE OF SELECTED CARBOHYDRATES ON THE DEVELOPMENT OF INTESTINAL MICROORGANISMS IN THE BABY PIG. R. D. Wilbur, L. Y. Quinn, D. V. Catron, V. W. Hays and V. C. Speer, *Iowa State College.*

Bacteriological examinations were made weekly on the feces of 48 baby pigs weaned at 2 weeks of age and carried on the experimental diets for 4 weeks with casein as the common source of protein and lactose or corn starch as the sole source of carbohydrate. At the end of this period half of the pigs were sacrificed and further studies were carried out on duodenal, ilial, cecal and rectal contents. In the fecal counts only slight changes with respect to diet were noted in the number of total aerobes, total anaerobes and lactobacilli; however, in most cases the coliforms, streptococci, staphylococci and molds and yeasts were reduced in number to a considerable extent when lactose was the carbohydrate. The sacrifice data showed that the number of organisms per gram of fresh content increased from duodenum to rectum

with the exception of the coliforms on the lactose diet and the molds and yeasts which demonstrated a slight decrease from cecal to rectal counts. These differences could not be accounted for by variations in moisture content of the feces. Again, little or no changes due to diet were found in total aerobes, total anaerobes or lactobacilli, but the coliforms, streptococci, staphylococci and molds and yeasts were all reduced in numbers by the lactose diet. This influence varied in degree in the different sections of the intestinal tract. Differences in gain and feed efficiency were highly in favor of the lactose diet.

84. COMPARATIVE PERFORMANCE OF PIGS WEANED AT 3 AND 8 WEEKS. M. J. Brinegar, E. C. Hornback and J. E. Hunter, *Allied Mills, Inc., Libertyville, Illinois.*

Arsonic compounds, complete pelleted rations and free-choice feeding of whole corn and pelleted concentrate were tested with 225 pigs raised in confinement and which had been weaned at either 3 or 8 weeks of age. Litters had been divided and regrouped at farrowing to eliminate heredity difference for subsequent comparisons. Results of weaning at 3 and 8 weeks were respectively: (1) weight at 9½ weeks, 51.6 lb., 44.1 lb.; (2) daily gain from 9½ weeks to 195 lb., 1.64 lb., 1.60 lb.; (3) feed per lb. gain, 3.34 lb., 3.31 lb. In one comparison with 126 hogs to market weight, additions to the ration of 0.01% arsanilic acid (AA) and 0.0025% 3-nitro, 4-hydroxy phenylarsonic acid (3-N) were compared to a control ration (C). Daily gains and feed per lb. gain were as follows: AA—1.64 lb. 3.30 lb.; 3-N—1.61 lb., 3.32 lb.; C—1.59 lb., 3.31 lb. Daily gains and feed per lb. gain from other comparisons with 129 hogs to market weight were: (1) 1.66 lb. and 3.35 lb. for a complete mixed meal ration (corn and concentrate) with minimum detectable waste; (2) 1.68 lb. and 3.26 lb. for a complete mixed pelleted ration; (3) 1.55 lb. and 3.39 lb. for whole shelled corn (dried to 14% moisture 5 months before start of test) fed free-choice with concentrate pellets. The hogs which were fed "free-choice" consumed 54% more concentrate than was mixed with corn in the "complete" rations, increasing the cost of gains considerably.

85. SUPPLEMENTATION OF THE SWINE GESTATION DIET WITH PYRIDOXINE. H. D. Ritchie, E. R. Miller, D. E. Ullrey, J. A. Hoefer and R. W. Luecke, *Michigan State University.*

Forty-two pregnant sows and gilts were lotted into two treatments to study the effects of supplemental pyridoxine in the gestation diet. The control lot received a typical gestation ration and the experimental lot received the same ration supplemented with 5 mg. pyridoxine hydrochloride per pound of diet. On two occasions, middle and late pregnancy, females from both groups were subjected to 48-hour confinement in metabolism cages to determine urinary excretion of xanthurenic acid, 4-pyridoxic acid and total creatinine before and after a tryptophan test load. At each of these times, complete hematology was performed on each animal. Two gilts on the control diet received 400 mg. of desoxypyridoxine per day in their diet during the last 3 weeks of gestation in an effort to develop a frank pyridoxine deficiency. After farrowing, the pyridoxine content of colostrum and later milk was determined on several sows and gilts from each lot. All pigs were weighed weekly from birth through 5 weeks of age. Hematological determinations were made on all pigs at birth and at 1, 3 and 5 weeks of age. The summary and analysis of 10,000 observational items of data were made. Supplementing the gestation diet with pyridoxine had no highly significant effect upon reproductive performance of the sows and gilts or the preweaning performance of their offspring. Thus, the control diet, containing 0.45 mg. B_6 per lb., appears to be adequate to meet the swine gestation pyridoxine requirement for normal reproduction.

86. A GENERATION STUDY OF THE ADEQUACY OF ALL-PLANT VERSUS PLANT AND ANIMAL PROTEIN RATIONS FOR SWINE. H. S. Teague and E. A. Rutledge, *Ohio Agricultural Experiment Station.*

A generation study was conducted in which all animals were kept under continuous dry lot management. Performance was measured on two ration treatments, the feeding of all plant rations or rations containing both plant and animal materials. Foundation stock consisted of two groups of 10 Duroc gilts. These females were farrowed three times and groups of gilt pigs selected from the farrow of sows on each ration treatment were used to continue the study. An attempt was made to farrow 6 of each 10 gilts and slaughter the remainder 55 to 57 days after breeding to obtain prenatal information. A total of 78 litters (755 pigs) were farrowed over the three-year period, including 12 litters of 4th generation pigs. Growing-finishing performance, breeding performance, prenatal reproductive performance through the first half of gestation and lactation performance appeared normal throughout the three-year period and were not consistently better on either ration treatment. Farrowing performance, including number born alive, birth weight and vigor at birth was considered satisfactory except for the spring farrow of one group of 2nd generation gilts fed all-plant rations. In five of six gilts, prenatal death of the litter had occurred approximately 80 days after breeding. Second farrowing performance of the same sows was normal. Neither litter size nor weight of pigs at 21 days was consistently greater on either of the two ration treatments. Continuous housing on concrete did not result in serious leg weakness in the sows or their pigs.

87. THE CONTRIBUTION OF VARIOUS DEHYDRATED FORAGE MEALS TO GROWTH PERFORMANCE AND LIVER STORES OF VITAMIN A IN SWINE. M. R. Cooper, A. J. Clawson and E. R. Barrick, *North Carolina Agricultural Experiment Station.*

Eight lots of 13 pigs each were used to test the relative efficiency of dehydrated alfalfa, Coastal Bermuda and Serecia lespedeza meals, as sources of provitamin A. Each forage was added to a white corn-soybean meal basal diet (fortified with minerals and B complex vitamins) at 3% and 10% levels. Two additional lots were fed the basal ration with and without supplemental vitamin A. All rations were fed at a level of 15% protein. Criteria used to evaluate each roughage were average daily gain, feed efficiency, blood serum levels and liver stores of vitamin A. The negative control group showed symptoms of avitaminosis A; listlessness, blindness, posterior incoordination and paralysis after about 90 days. They gained less ($P<0.01$) than the other treatment groups. The average daily gain or the positive control group (basal plus vitamin A palmitate to provide 1,021 U.S.P. units of vitamin A activity per lb. of ration) was not significantly different from the 3% forage treatments, but was greater ($P<0.05$) than for the 10% forage treatments. The three forages fed as 3% of the diet resulted in higher daily gain and less feed per 100 lb. of gain ($P<0.05$) than when fed at 10% levels. Differences between forages within the 3% and 10% feeding levels were non-significant. Blood serum vitamin A levels for the positive control and 10% level of forages were not significantly different. Blood serum and liver stores of vitamin A were higher ($P<0.01$) in pigs fed 10% than those receiving 3% forage. The livers of the positive control group contained more ($P<0.01$) and the negative control group contained less ($P<0.01$) vitamin A than the livers of other treatment groups.

88. THE EFFECT OF ATARAX IMPLANTS, WITH OR WITHOUT DIETHYLSTILBESTROL, ON STEERS FATTENED ON PASTURE AND IN DRYLOT. H. L. Chapman, Jr., J. R. Crockett, A. Z. Palmer and R. W. Kidder, *Everglades Experiment Station, University of Florida.*

One hundred and twenty 2-year-old steers were divided into 15 lots of eight animals each and fed for a 131-day period to study the interrelation of atarax im-

plants with diethylstilbestrol administered, orally and by implant, to steers being fattened on pasture and in drylot; and to determine the effect that level of concentrate feed intake had on this interrelationship. Groups receiving oral diethylstilbestrol were given 10 mg. daily in the feed; those implanted, 24 mg. at the beginning of the experiment. One-half of the animals in each lot received 60 mg. of atarax implanted at the beginning of the experiment. Limited fed animals received 6 lb. of concentrate feed daily. Full fed groups received this mixture *ad lib*. Either form of diethylstilbestrol significantly increased average daily gains ($P<0.05$), but there was no significant effect attributable to method of administration of the compound. Atarax increased average daily gain significantly ($P<0.05$) for animals receiving concentrate feed *ad lib*, but not for animals receiving either limited or no concentrate feed. Average daily gains were significantly higher ($P<0.05$) for animals receiving diethylstilbestrol and atarax, on full feed, than diethylstilbestrol alone. Diethylstilbestrol did not affect intransit shrink, dressing percent or cooler shrink but did produce more improvement ($P<0.05$) in grade. Animals receiving atarax had a higher average intransit shrink ($P<0.01$) and dressing percent ($P<0.05$), a lower average cooler shrink ($P<0.01$) and the same improvement in grade as those not receiving atarax.

89. FEED ADDITIVES AND IMPLANTS FOR FATTENING BEEF CALVES. J. K. Matsushima, D. C. Clanton, G. N. Baker and V. H. Arthaud, *University of Nebraska.*

One hundred sixty Hereford steer calves were used in two creep feeding and fattening trials. Pelleted creep rations, with and without Aureomycin, were fed to calves from 3 to 4 weeks of age until weaned. In both trials the calves which received approximately 20 mg. Aureomycin daily weighed less than the controls at weaning time. Within a few weeks after weaning the calves were fed a fattening ration. In the first fattening trial, 40 calves that received no antibiotic in the creep ration were divided into four lots with the following treatments: Treatment I, control; Treatment II, 10 mg. stilbestrol; Treatment III, single Synovex implant initially; and Treatment IV, 10 mg. of stilbestrol derivative (3,3' allyl diethylstilbestrol) orally. These treatments were duplicated with the 40 calves which received Aureomycin in the creep ration. The 80 calves from the second creep feeding test were also included in a fattening test with treatments duplicating, with one exception, those used in the first trial. Treatment IV was replaced with another which consisted of 20 mg. tranquilizer (triflupromazine) plus 10 mg. stilbestrol. Both of these additives were administered orally with the feed. The combined results from the two feeding trials showed that oral administration of stilbestrol and the Synovex implant was nearly equal in increasing weight gains and feed efficiency over those of the controls. Addition of the tranquilizer to a ration containing 10 mg. of stilbestrol had no beneficial or harmful effect on animal performance as compared to Treatment II. Comparisons were made of animal gains, feed utilization, carcass data and various carcass and accessory reproductive tissue measurements.

90. IMPLANTATION OF STILBESTROL AND TESTOSTERONE IN FATTENING STEERS AND HEIFERS. Earle W. Klosterman, L. E. Kunkle and A. L. Moxon, *Ohio Agricultural Experiment Station.*

Four experiments have been completed in which implantations of stilbestrol, testosterone and combinations of the two were made in fattening steers and heifers. A total of 172 heifers and 75 steers were included in these studies. Stilbestrol was implanted in pellet form and testosterone in a paste-type carrier. Implantations of stilbestrol (36–72 mg. per head) significantly increased rate of gain in steers and heifers. This increase, however, was greater and more consistent in steers than heifers. Testosterone implantations of 240–400 mg. per head significantly increased growth

rate of heifers but implantations of 240 mg. had no apparent effect on steers. A combination of stilbestrol and testosterone implanted in heifers produced gains greater than those obtained from either one alone and approached the response obtained from stilbestrol in steers. Stilbestrol implanation tended to lower slightly the grade of steer carcasses but neither stilbestrol nor testosterone appeared to affect the grade of heifer carcasses. No severe side-effects, such as prolapse, were observed in any of the animals treated. Hormone treatments were on a within lot basis, consequently feed efficiency data were not obtained.

91. EFFECT OF ENERGY LEVEL ON PROTEIN REQUIREMENT OF LAMBS FATTENED WITH AND WITHOUT STILBESTROL. J. R. Jones, D. E. Hogue and G. L. Hunt, *Cornell University*.

One hundred ninety-two western whiteface feeder lambs were randomly assigned to a 2^3 factorial experiment with duplicate lots of 12 lambs in each of eight treatment groups. The variables included two levels each of estimated net energy, ENE, and estimated digestible protein fed with and without oral stilbestrol. Energy and protein levels were set at 90 and 120% of the minimum recommendations (Morrison, 22nd ed.). A ration of alfalfa grass hay, corn silage, corn and soybean oil meal was full fed to a maximum allowable amount based on the treatment group. Roughage was kept constant between lots and the roughage to concentrate ratio was kept constant within each lot. Differences were detected ($P<0.01$) in gain and grade between protein levels and an interaction detected between protein and energy levels. The average daily gain, ENE consumption (percent of expected), feed efficiency (therms ENE per lb. gain) and final liveweight grade (choice, 8; good, 6; etc.) of the energy-protein groups were, respectively: HEHP, 0.36, 90, 4.76, 6.4; HELP, 0.27, 79, 5.63, 5.3; LEHP, 0.33, 99, 4.53, 5.6; LELP, 0.30, 96, 4.69, 5.5. Apparently the low protein level was sufficient for the low energy ration but not for the high energy groups indicating that the protein requirement may be affected by the energy content of the ration. Stilbestrol significantly ($P<0.01$) increased gain by 20% and feed efficiency by 18% and decreased grade about one-third of a grade. No interaction was detected between stilbestrol and either protein or energy.

92. INFLUENCE OF TIME AND NUMBER OF ESTRADIOL-PROGESTERONE IMPLANTS ON RATE OF GAIN AND TOTAL GAIN OF BEEF CALVES DURING A 324-DAY GROWING AND FINISHING PERIOD. F. C. Hinds, D. L. Taggart, W. W. Albert, A. L. Neumann and G. E. Mitchell, Jr., *University of Illinois*.

Forty-eight choice Hereford steer calves averaging 437 lb. were divided into four treatment groups at the beginning of a 324-day growing and finishing period. Steers in Group I received no hormone treatment. Each steer in Group II received a single Synovex implant (20 mg. of estradiol and 200 mg. of progesterone) at the beginning of the experiment. Each steer in Group III received an initial Synovex implant plus an additional implant 140 days later. Steers in Group IV received the second implant but not the first. The feeding program was divided into three phases. During the initial 140-day wintering phase, all steers were fed a full-feed of corn silage plus 1½ lb. per head per day of soybean oil meal. For the next 114 days they were self-fed ground ear corn with or without soybean oil meal either on pasture or in dry-lot with alfalfa silage substituted for pasture. A full-feed of ground shelled corn, alfalfa hay, and soybean oil meal will be fed in dry-lot during the final 68-day finishing phase. After 224 days average total gains and average daily gains were: Group I, 417 and 1.86; Group II, 495 and 2.21; Group III, 500 and 2.23; and Group IV, 459 and 2.05.

93. DYNAFAC AND STILBESTROL IMPLANTS WHEN USED WITH COMPLETELY PELLETED RATIONS FOR FATTENING CATTLE. O. O. Thomas, Harley Jordan and F. S. Willson, *Montana State College.*

Two trials were conducted with yearling beef steers to determine the value of various feed additives in cattle fattening rations. In Trial I, 12 steers in each of eight lots were fed a basal ration of two-thirds barley and one-third beet pulp with grass hay being used as a roughage. The treatment and daily gains of steers during the 114-day feeding experiment were as follows: Lot 1, control, 2.33; Lot 2, 36 mg. DES implant, 2.59; Lot 3, 10 mg. DES daily, 2.63; Lot 4, Synovex implant, 2.55; Lot 5, Dynafac control, 2.45; Lot 6, Dynafac plus 36 mg. implant, 2.85; Lot 7, Dynafac plus 10 mg. DES daily, 2.60; Lot 8, Dynafac plus Synovex implant, 2.67. In Trial II, eight yearling Hereford steers in each of five lots were self-fed a ration in meal or pelleted form. The ration consisted of barley, 40%; beet pulp, D.M., 20%; alfalfa, ground, 30%; wheat mixed feed, 5%; and molasses, 5%. Average daily weight gains and feed required per 100 lb. gain at the end of the first 84 days of the trial were as follows: Lot 1, meal ration plus alfalfa hay, 2.86, 652; Lot 2, completely pelleted ration, 2.69, 648; Lot 3, completely pelleted ration plus straw *ad lib,* 2.89, 632; Lot 4, completely pelleted ration with the addition of 200 gm. of Dynafac per ton, straw *ad lib,* 3.40, 585; Lot 5, completely pelleted ration, Dynafac, straw *ad lib,* 36 mg. Stilbestrol implant 3.41, 596.

94. EVALUATION OF GIBBERELLIN IN LAMB RATIONS. W. H. Hale, W. C. Sherman, W. M. Reynolds and H. G. Luther, *Chas. Pfizer & Co., Inc., Terre Haute, Indiana.*

Lambs were self-fed a pelleted basal ration comprising alfalfa meal 35, ground corn 52, cane molasses 10, urea 1 and bone meal 1. Twelve wether lambs were fed per treatment with two replicates of 12 for the controls in each of three experiments. Average daily gain (lb.) and lb. feed per lb. of gain were: Experiment 1—(63 days) controls, 0.558, 6.98; gibberellin 1.0 gm. per ton ration, 0.633, 6.61. Experiment 2 (42 days) controls, 0.648, 6.60; gibberellin 0.1 gm. per ton, 0.736, 6.08; gibberellin 1.0 gm. per ton, 0.651, 6.40; (53 days) controls, 0.688, 6.50; gibberellin 0.1 gm. per ton, 0.671, 6.94; gibberellin 1.0 gm. per ton, 0.649, 6.82. Experiment 3—(42 days) controls, 0.414, 8.05; gibberellin 0.1 gm. per ton, 0.442, 7.28; gibberellin 1.0 gm. per ton, 0.400, 8.80; (71 days) controls, 0.363, 9.36; gibberellin 0.1 gm. per ton, 0.339, 9.35; gibberellin 1.0 gm. per ton, 0.332, 10.22. In experiment 1 both growth and feed efficiency were enhanced by 1.0 gm. gibberellin per ton. In experiments 2 and 3 an initial response was observed through 42 days, but was not maintained throughout the trials.

95. EFFECT OF ANIMAL FAT OR SALT TO LIMIT GRAIN INTAKE ON THE PERFORMANCE AND CARCASS CHARACTERISTICS OF PASTURE FATTENED STEERS AND THE INFLUENCE OF DIETHYLSTILBESTROL AND CHLORTETRACYCLINE. M. B. Wise, E. R. Barrick and T. N. Blumer, *North Carolina Agricultural Experiment Station.*

Sixty-eight yearling steers were used in two experiments to investigate methods of limiting concentrate intake of fattening cattle self-fed grain on Ladino clover-grass pasture and to study the effects of diethylstilbestrol and chlortetracycline on performance and carcass characteristics. In the first experiment animal fat (yellow grease) and salt were compared to limit grain intake. One-half of the animals receiving each treatment were implanted with 24 mg. of stilbestrol. Mean values for daily gain in lb., daily concentrate intake in lb. and corn or corn plus fat/lb. of gain in lb. for the two groups were respectively: Fat limited, 2.55, 7.55, 2.96; Salt limited, 2.38, 8.00, 3.10. Carcass measurement criteria showed that the fat limited

steers had more finish as measured by separable fat in the 9–10–11 rib cut, rind thickness, and marbling. By the same criteria the steers that did not receive stilbestrol had more finish than those receiving stilbestrol. In the second trial, 28 steers were self-fed grain containing 10% animal fat with one-half the steers receiving 75 mg. per head daily of chlortetracycline in the grain mixture. One-half the animals in each group were implanted with stiibestrol. The 112-day means for daily gain, daily concentrate intake and concentrate per lb. of weight gain were respectively: Control, 2.81, 8.19, 2.91; Chlortetracycline, 2.80, 5.16, 1.84. Increases in daily gain due to stilbestrol were 0.81 lb. during the first experiment and 0.48 lb. in the second.

96. EFFECTS OF TRIMETHYLALKYLAMMONIUM STEARATE, 3, 3′ DIALLYL HEXESTEROL, OXYTETRACYCLINE, FAT, CHOLINE AND LECITHIN ON STEER PERFORMANCE. I. A. Dyer and W. E. Ham, *State College of Washington.*

Forty-eight yearling steers were randomly allotted to an experiment having eight variables. These steers were individually fed an all pelleted ration for 89 days. The experiment was designed so that 12 steers were on each main treatment. Rates of gain and efficiency of feed utilization were: 3.08, 534; 3.18, 553; 3.09, 554; 2.97, 524; 3.29, 550; 3.22, 544; 2.95, 526 and 2.88, 545 for steers on the control, tetra alkylammonium stearate, choline, lecithin, control, 3, 3′ diallyl hexesterol, oxytetracycline and tallow fed groups, respectively. Total microbial activity, MM Hg. per minute, was 3.13, 3.84, 2.99, 2.19, 2.82, 3.35, 3.03 and 2.45 for the above treatments respectively. Digestible energy was determined.

97. EFFECT OF STILBESTROL, PELLETING AND CONCENTRATE TO ROUGHAGE RATIO ON THE PERFORMANCE AND CARCASS QUALITY OF FATTENING LAMBS. R. H. Hartman, D. L. Staheli, R. G. Holleman and L. H. Horn, *Swift & Company.*

Six hundred ninety-eight head of Texas old crop feeder lambs averaging 77.6 lb. were allotted to eight treatments in a 2^3 factorial designed experiment. The treatments for the 53-day feeding period consisted of two types of rations self-fed in two forms (pellet and meal) with and without stilbestrol. The concentrate to roughage ratio for the two rations varied from 71% concentrate and 29% roughage (high concentrate) to 41% concentrate and 59% roughage (high roughage). No significant differences were observed between rations in rate or cost of gain. Lambs fed the high concentrate ration required 12% less feed per hundredweight gain and yielded 1.15% more than the lambs fed the high roughage ration. Pelleting the high roughage ration increased gain by 15%. Conversely, pelleting the high concentrate ration depressed gains by 14%. Feed efficiency of either of the rations was not significantly affected by pelleting. Pelleting increased the feed cost per hundredweight gain by $1.53 and $1.88, respectively, for the high concentrate and high roughage fed lambs. Feeding stilbestrol (0.5 mg. per lb. feed) significantly ($P<.05$) improved average daily gain and feed efficiency over the control lambs (0.56, 0.48 and 9.23 lb., respectively) and saved $2.72 in feed cost per hundredweight gain. This response from stilbestrol was greater on lambs fed the high roughage ration than on those receiving the high concentrate ration. Effect of stilbestrol upon carcass grade and quality was comparable with the control lambs. However, stilbestrol fed lambs had 14.4% of the carcasses with yearling joints while the controls had only 2.3%.

98. ESTROGEN-ANDROGEN COMBINATIONS FOR FATTENING WETHER LAMBS. R. G. Eggert and W. T. Akers, *Research Division, American Cyanamid Company.*

Two experiments were conducted in which 84 black-face wether lambs were fed a ration consisting of 50% poor quality chopped timothy and alfalfa hay and

50% grain mixture. In each experiment lots 1, 2 and 3 received the basal grain mix, while lots 4, 5 and 6 received the same ration plus 2 mg. of diethylstilbestrol per lb. of grain mix. Lots 1 and 4 received no androgen; lots 2 and 5 received weekly I.M. injections of 0.1 mg. testosterone propionate per kilogram of body weight; and lots 3 and 6 received weekly I.M. injections of 1.0 mg. of testosterone propionate per kilogram body weight. The average daily gains and feed per lb. of gain for an 84-day feeding period in experiment 1 were 0.41, 7.45; 0.42, 7.11; 0.47, 6.56; 0.45, 6.80; 0.48, 6.45; and 0.56, 6.13 for lots 1 to 6, respectively. The corresponding data for a 56-day feeding period in experiment 2 were 0.42, 7.25; 0.50, 6.58; 0.60, 5.67; 0.61, 5.42; 0.67, 5.09; and 0.68, 5.32. In experiment 3, forty-two white-face wether lambs were allotted to six lots and fed a complete pelleted ration with the following treatments: Lot 1, basal; Lot 2, 0.8 mg. of diethylstilbestrol per lb. of ration; Lot 3, 1.0 mg. of testosterone propionate intramuscularly per kilogram body weight per week; Lot 4, same as 2 plus 1.0 mg. of testosterone propionate intramuscularly per kilogram body weight per week; Lot 5, 20 mg. of methyltestosterone per lb. of ration; and Lot 6, same as 5 plus 0.8 mg. of diethylstilbestrol per lb. of ration. The average daily gains and feed per lb. of gain for an 84-day feeding period were 0.49, 6.65; 0.65, 5.67; 0.55, 5.88; 0.57, 6.08; 0.64, 5.70; and 0.73, 5.56 for lots 1 to 6, respectively.

99. STUDIES OF OLEANDOMYCIN AT NUTRITIONAL LEVELS IN LAMB AND STEER RATIONS. W. M. Reynolds, W. H. Hale, W. C. Sherman and H. G. Luther, *Chas. Pfizer & Co., Inc., Terre Haute, Indiana.*

Oleandomycin was tested as a growth promoter in three trials with fattening lambs and in one with steers. The lambs were self-fed a pelleted ration comprising alfalfa meal 35, ground corn 53, cane molasses 10, urea 1, and bone meal 1. Each treatment group contained 12 lambs and controls were replicated. Duration was 63, 53 and 56 days in experiments 1, 2 and 3, respectively. Daily rates of gain (lb.) and lb. feed per lb. gain were as follows: Experiment 1—controls, 0.558, 6.98; 2 gm. oleandomycin per ton ration, 0.664, 6.06; 15 gm. oleandomycin, 0.556, 7.00; Experiment 2—controls, 0.688, 6.50; 2 gm. oleandomycin per ton ration, 0.712, 6.77. Experiment 3—controls, 0.363, 9.36; oleandomycin 2 gm. per ton ration, 0.404, 8.24; oleandomycin 6 gm., 0.420, 8.43; oxytetracycline 15 gm., 0.380, 9.08; and oleandomycin 2 gm. plus oxytetracycline 15 gm., 0.426, 8.08. The oleandomycin, except for the 15 gm. level, improved rates of gain. It improved feed efficiencies, except at 15 gm. and in one group at 2 gm., and tended to improve carcass grades and dressing percentages. The steers were full-fed cracked shelled corn, limited alfalfa hay and a protein supplement. During the last 29 days of a 169-day steer fattening trial, two groups of eight were fed, respectively, oleandomycin 20 mg. per head per day, or oxytetracycline 80 mg. per head per day. Average daily gain (lb.) and lb. feed per lb. gain were: controls (16 animals) 2.66, 9.82; oleandomycin 20 mg., 3.73, 7.20; oxytetracycline 80 mg., 3.16, 8.40. Thus, an improvement in rate of gain and feed efficiency was shown for this relatively low level of oleandomycin fed to steers.

100. EFFECTS OF BACTERICIDAL AGENTS ON THE CONTROL OF SCOURS AND ON THE GROWTH OF PIGS. C. H. Chaney and C. E. Barnhart, *University of Kentucky.*

Two trials involving 76 young pigs were conducted to compare various feed additives. A corn soybean meal basal ration was fed. In trial 1 the various additives per ton of ration were as follows: (1) none, (2) 10 gm. chlortetracycline, (3) 100 gm. furazolidone, (4) 180 gm. trimethylalkyl ammonium stearate, (5) 12 gm. hygromycin B, (6) 90 gm. arsanilic acid, (7) 18 gm. arsenosobenzene, (8) 45 gm. 3-nitro 4-hydroxyphenyl arsonic acid, (9) 50 gm. chlortetracycline, 90 gm. arsanilic acid, 12 gm. hygromycin B, 100 gm. furazolidone, 2% flavoring, and 5% corn oil. The

average daily gain in lb. and the lb. of feed per lb. of gain respectively were as follows: (1) 1.25, 2.53; (2) 1.24, 2.65; (3) 1.37, 2.50; (4) 1.14, 2.66; (5) 1.18, 2.76; (6) 1.24, 2.64; (7) 1.20, 2.52; (8) 1.22, 2.60; (9) 1.42, 2.27. In trial 2, furazolidone was fed to lots 1 through 4 at the following levels: 0, 25, 50, and 100 gm. per ton of ration. The average daily gain in lb. and the lb. of feed per lb. of gain respectively were as follows: (1) 1.11, 3.03; (2) 1.05, 2.82; (3) 1.06, 2.93; (4) 1.12, 3.02. Trials 1 and 2 were terminated when the pigs reached 100 and 125 lb. respectively.

101. EFFECT OF HYGROMYCIN AND A COMBINATION OF ANTIBIOTICS ON GROWING-FINISHING SWINE. J. H. Conrad and W. M. Beeson, *Purdue University*.

Two experiments (one on concrete and one on pasture) were conducted with a total of 160 thirty-lb. Duroc weanling pigs fed complete mixed rations to market weights. Four of eight lots in each experiment were wormed twice with piperazine adipate and four lots were not wormed. Treatments fed continuously were: Control (Cont.); hygromycin B (Hygro.), 12 million units/ton; antibiotic combination (Anti.) at a level of 20 gm. per ton—chlortetracycline, 5; penicillin, 2.5; oxytetracycline, 5; and, zinc bacitracin, 7.5; hygromycin B + antibiotics, both at previous levels, (Hygro. + Anti.). The treatments, daily gains and feed per 100 lb. of gain were: Concrete unwormed—Cont., 1.48 and 361; Hygro., 1.36 and 374; Anti., 1.61 and 350; Hygro + Anti., 1.63 and 359; Concrete, wormed—Cont., 1.58 and 356; Hygro, 1.57 and 350; Anti., 1.80 and 361; Hygro. + Anti., 1.64 and 342. Similar data for the pasture experiment were: Pasture, unwormed—Cont., 1.40 and 304; Hygro., 1.38 and 298; Anti., 1.57 and 328; Hygro. + Anti., 1.59 and 296; Pasture, wormed—Cont., 1.40 and 308; Hygro., 1.29 and 292; Anti., 1.62 and 298; Hygro. + Anti., 1.64 and 301. Significant differences were found between treatments as indicated by daily gains. Complete data were obtained regarding roundworm, nodular worm and whipworm infestation and control as indicated by ova counts and worms recovered at slaughter.

102. EFFECTS OF AUREOMYCIN AND HYGROMYCIN B ON WORMED AND NON-WORMED PIGS. D. M. Thrasher, H. Thielen, Paul B. Brown and Sam L. Hansard, *Louisiana State University*.

Two studies involving 72 weanling Chester White pigs have been conducted to investigate the effects of aureomycin and three levels of hygromycin B on wormed and non-wormed pigs. In Trial I, 48 pigs were divided equally among eight concrete pens. Lots 5 through 8 were wormed with piperazine citrate prior to being placed on experiment. The treatments were as follows: Lots 1 and 5, basal ration containing no antibiotics; Lots 2 and 6, 10 mg. aureomycin/lb.; Lots 3 and 7, 6 mg. hygromycin B/lb.; Lots 4 and 8, combination of aureomycin and hygromycin B. Average daily gains through 70 days for Lots 1 to 8 were 1.32, 1.35, 1.35, 1.49, 1.47, 1.45, 1.29, and 1.31 lb., respectively. Non-wormed pigs receiving aureomycin and/or hygromycin B required an average of 8% less feed per cwt. of gain, but no improvement in efficiency was noted with previously wormed pigs. From 56 to 70 days, pigs receiving hygromycin B consumed an average of 0.75 lb. less feed per day than controls. In Trial II, 24 non-wormed pigs were divided among four concrete pens and fed a basal ration containing aureomycin plus levels of 3, 6, and 12 mg. of hygromycin B/lb. of total feed. Average daily gains at 56 days were 1.40, 1.50, 1.43, and 1.33 lb., respectively. Daily feed intake at the 12 mg. level was 0.3 lb. below that of controls. Differences in feed efficiency were small. Bi-weekly fecal worm egg counts in both trials showed a sharp and marked decline in ascarid eggs when non-wormed pigs received hygromycin B. The count in all wormed pigs remained low. Consideration will be given to effects on nodular and whipworm egg counts and total worm load at completion of the test.

103. A COMPARISON OF DIFFERENT LEVELS AND COMBINATIONS OF AUREOMYCIN, BACITRACIN AND PENICILLIN, AND THE FEEDING OF TETRA-ALKYLAMMONIUM STEARATE AND HYGROMYCIN A AND B TO PIGS IN DRY LOT AND ON PASTURE. E. A. Rutledge and H. S. Teague, *Ohio Agricultural Experiment Station.*

A total of 32 lots each of eight pigs on concrete and six lots each of 20 pigs on pasture were used in a 3-season study to determine the value of certain antibacterial agents in swine feeds. The treatments and/or amount of additive per ton of feed were: (1) control; (2) 50 gm. tetra-aikylammonium stearate; (3) 100 gm. tetra-alkylammonium stearate; (4) 10 gm. Aureomycin; (5) 20 gm. Aureomycin; (6) 5 gm. Aureomycin, 3.75 gm. zinc bacitracin, 1.25 gm. procaine penicillin; (7) 10 gm. Aureomycin, 7.5 gm. zinc bacitracin, 2.5 gm. procaine penicillin; (8) 10 gm. sulfaquinoxaline, 10 gm. streptomycin; (9) 7.5 gm. zinc bacitracin, 2.5 gm. procaine penicillin; (10) 15 gm. zinc bacitracin, 5 gm. procaine penicillin; (11) 5 lb. "Hygromix" (hygromycin A and B). Treatment number, average daily gain and feed/100 lb. gain, respectively, were: Trial I (dry lot): (1) 1.60, 353; (2) 1.57, 356; (4) 1.66, 346; (5) 1.76, 346; (6) 1.62, 355; (7) 1.77, 330; (8) 1.72, 335; (11) 1.64, 345. Trial II (dry lot): (1) 1.57, 369; (3) 1.63, 358; (4) 1.57, 363; (5) 1.71, 353; (6) 1.67, 351; (7) 1.80, 348; (8) 1.68, 351; (9) 1.69, 353; (10) 1.73, 351. Trial II (pasture): (1) 1.55, 335; (2) 1.56, 326; (4) 1.68, 330; (7) 1.72, 315; (8) 1.65, 329; (11) 1.59, 323. In dry lot, treatments 5, 7, 8, 9 and 10 improved both rate of gain and efficiency of feed utilization. In Trials I and II, 20 gm. of Aureomycin per ton resulted in 6.0% and 8.9% increases in gain, respectively, over the 10 gm. level. A combination of three antibiotics (treatment 7) resulted in the best overall performance both in dry lot and on pasture. "Hydromix" (11) was effective in the control of internal parasites.

104. FIELD EVALUATION OF CHLORTETRACYCLINE SUPPLEMENTATION OF LACTATING SOW AND STARTING, GROWING, FINISHING PIG RATIONS. R. F. Elliott; D. D. Johnson and H. E. Gouge, *American Cyanamid Co., Princeton, N. J.*

To determine the effects of a complete chlortetracycline feeding program on the performance of swine under farm conditions, a total of 198 sows in seven herds were divided into four equalized treatment groups. Two groups of sows received no antibiotic and two groups received 200 gm. chlortetracycline per ton of ration for 10 to 14 days before and 7 days after farrowing and then 50 gm. chlortetracycline until their pigs were weaned. Pigs suckling the sows in one control and in one antibiotic-supplemented group were offered a creep ration containing 100 gm. chlortetracycline per ton from 3 weeks to weaning at approximately 8 weeks. Pigs from each litter were then allotted to 3 groups that received: (1) the basal ration (2) basal supplemented with 50 gm. chlortetracycline per ton to 75 lb. and 20 gm. to market weight (3) 50 gm. continuously to market weight. There was less mortality ($P<.01$) among the pigs suckling antibiotic-supplemented sows (11 and 12%) than among those suckling the control sows (17 and 17%) up to 3 weeks of age and to weaning (12 and 13% *vs.* 20 and 21%). From 3 weeks to weaning the pigs receiving the antibiotic supplemented creep feed gained significantly faster ($p = .01$) than the non-supplemented pigs (0.75 and 0.78 lb. *vs.* 0.66 and 0.69 lb. per day). From weaning to market the average daily gains of both groups of antibiotic-supplemented pigs were equal and significantly greater (0.11 lb. per day) than the control pigs. The pigs in the supplemented groups consumed slightly more feed per day, required the same amount of feed per lb. gain, averaged 6 and 9 lb. heavier at market, returned more dollars over feed cost and sold for a higher price on a grade and yield basis than the control pigs.

105. A NEW ANTIBIOTIC, OLEANDOMYCIN, IN SWINE RATIONS. N. D. Magruder, W. C. Sherman, W. M. Reynolds and H. G. Luther, *Chas. Pfizer & Co., Inc., Terre Haute, Indiana.*

A total of 200 hybrid baby pigs (7–10 days of age) and 94 growing-finishing swine were studied in nine experiments to test growth-promoting action of oleandomycin in comparison with oxytetracycline and with mixtures of the two antibiotics. In experiments 1 and 2 with baby pigs to evaluate oleandomycin alone, controls gained 0.73 and 0.70 lb. per day, respectively, and gains of 0.82 to 0.87 lb. were observed with oleandomycin levels of 10, 25 and 50 gm. per ton. In two additional baby pig experiments, controls gained 0.60 and 0.80 lb. per day and oleandomycin at 2.5, 5.0 or 10.0 gm. per ton, or oxytetracycline at 50 gm. per ton produced growth increments of 4% to 8% whereas these levels of the two antibiotics fed simultaneously produced increments up to 20%. In five trials with growing-finishing pigs in which gains of controls ranged from 1.32 to 1.66 lb. per day, addition of oleandomycin only at levels of 2 to 10 gm. per ton or of oxytetracycline at 10 to 20 gm. per ton produced growth responses of 1% to 6%, whereas simultaneous use of oleandomycin at 2 gm. per ton with oxytetracycline at 10 gm. or 20 gm. brought increases over controls of 4% to 10%. Feed efficiency responses were more variable and of lower magnitude than growth effects. Total bacterial counts on fecal samples of 0, 4 and 6 weeks displayed no differences between treated groups and controls with any type of antibiotic supplementation.

106. THE LACK OF DELETERIOUS EFFECT OF ARTIFICIALLY ADMINISTERING CULTURES OF *CANDIDA ALBICANS* TO GROWING SWINE WHICH ARE RECEIVING CHLORTETRACYCLINE AND/OR NYSTATIN. R. G. Eggert, W. T. Akers and R. F. Elliott, *American Cyanamid Company.*

In experiment 1, fifty weanling pigs were allotted to ten uniform groups and fed a ration consisting of ground yellow corn, 62.0; soybean oil meal, 16.1; ground oats, 14.9; meat and bone scraps, 2.5; dried whey, 2.5; steamed bonemeal, 0.5; iodized salt, 0.5; ground limestone, 0.6; and vitamins and trace minerals, 0.3. The following levels (gm. per ton of ration) of chlortetracycline and nystatin were fed: Lot 1—50, 0; Lot 2—50, 12.5; Lot 3—50, 25; Lot 4—50, 50; Lot 5—50, 100; Lot 6—50, 200; Lot 7—0, 50; Lot 8—0, 0; Lot 9—0, 0. In addition lots 1 to 8 received a culture of approximately 9 x 10^7 cells of *Candida albicans* per pig daily. The average daily gains and feed per pound of gain for a 49-day period were 1.65, 3.00; 1.60, 3.04; 1.62, 3.06; 1.71, 2.90; 1.60, 3.14; 1.59, 3.10; 1.68, 3.00; 1.50, 2.82; and 1.34, 2.94 for lots 1 to 9, respectively. In experiment 2, thirty-two weanling pigs were allotted to eight uniform groups which received the following treatments: Lots 1 & 2—basal; Lots 3 & 4—50 gm. of chlortetracycline; Lots 5 & 6—50 gm. of nystatin; and Lots 7 & 8—50 gm. of chlortetracycline and 50 gm. of nystatin per ton of feed. In addition, lots 1, 3, 5 & 7 received a daily culture of *Candida albicans* as in experiment 1. The average daily gains and feed per pound of gain for a 56-day period were 1.70, 2.79; 1.58, 2.89; 1.68, 2.75; 1.62, 2.83; 1.79, 2.57; 1.72, 2.71; 1.81, 2.64; and 1.71, 2.73 for lots 1 to 8 respectively. The combined average daily gain and feed per pound of gain for all pigs receiving the *Candida albicans* in experiment 2 were 1.74 and 2.69 compared to 1.66 and 2.79 for all pigs not receiving it.

107. EFFECT OF 3-NITRO-4-HYDROXYPHENYLARSONIC ACID ON GROWTH, FEED EFFICIENCY AND CARCASS QUALITY OF GROWING-FINISHING SWINE. J. R. Foster, V. C. Speer, V. W. Hays, D. V. Catron, *Iowa State College.*

Four experiments were conducted with 214 growing-finishing pigs initially weighing approximately 35 lb. to study the effect of 3-nitro-4-hydroxyphenylarsonic acid

(3-nitro) and protein levels on gains, feed efficiency and backfat as measured by the live probe. In Experiment I the control pigs gained 0.1 lb. per day faster and had 9% more backfat than the pigs receiving the arsenical. In Experiment II four levels of 3-nitro were fed—0, 0.0025%, 0.005% and 0.01%. The average daily gain and feed efficiency were essentially the same for the control pigs as those receiving the arsenical. The pigs were probed at 115 lb. and again at 200 lb. with a correlation coefficient between the two probes of + 0.80. At 115 lb. the arsenical fed pigs had 12% less backfat which was statistically significant ($P<.05$). At 200 lb. there was a 7% difference in backfat in favor of the treated pigs. In Experiment III two levels of protein were fed with and without the arsenical. The high protein rations contained 20% protein up to 50 lb., 18% from 50 to 125 lb. and 16% from 125 to 200 lb. The low protein rations for the corresponding weight ranges contained 14%, 12% and 10% protein. A 4% improvement in rate of gain was observed with the addition of the arsenical and the higher protein rations resulted in 4% faster gains. The backfat measurements at 130 lb. for the low protein, low protein + 3-nitro, high protein, and high protein + 3-nitro were 1.21, 1.20, 1.07, and 1.03 in. respectively. In Experiment IV the ration treatments were: control (C), C + 3-nitro, C + Copper sulfate, and C + 3-nitro + copper sulfate fed to 200 lb. with average daily gains of 1.31, 1.35, 1.50, and 1.47 lb., respectively, and backfat measurements at 140 lb. of 1.14, 1.06, 1.17, and 1.20 in., respectively.

108. THE USE OF TRIIODOTHYRONINE IN THE RATION OF LACTATING SOWS AND GROWING-FINISHING PIGS. H. D. Wallace, W. F. Davis, C. E. Norris, G. E. McCabe, G. E. Combs and A. Z. Palmer, *University of Florida.*

Eighty-six sows were used in four trials to determine the value of feeding triiodothyronine from 3-day prefarrow through 14 days of lactation. In the first three trials 600 mg. per ton was fed and in the fourth trial 300 mg. Results, measured in terms of survival and weight gains of pigs, showed no significant advantage for the treated sows. Daily feed consumption was approximately the same for the treated and untreated sows; however, the treated sows lost an average of 15.4 lb. more body weight during the experimental period ($P<.01$). Body temperature was not elevated by triiodothyronine. Two trials were conducted with the growing-finishing pig. Four levels of triiodothyronine (0, 25, 50 and 75 mg./ton) and two levels of protein (14 and 21%) were studied in trial 1. Eighty weanling pigs, divided into eight treatment groups and fed in 16 replicated lots of five animals each, were fed a corn-soybean meal ration on concrete. Gains and feed conversion data indicated no significant response to the imposed treatments. In a second trial 40 pigs were fed as follows: Control; 50 mg. entire feeding period; 50 mg. after 110 lb. body wt.; and 50 mg. after 150 lb. body weight. Pigs fed 50 mg. triiodothyronine for the entire feeding period gained significantly faster ($P<.05$) than pigs on the other treatments.

109. EFFECT OF ESTROGENIC AND ANDROGENIC COMPOUNDS UPON GROWTH AND CARCASS COMPOSITION OF SWINE. G. W. Thrasher, T. W. Perry, F. N. Andrews, W. M. Beeson and Martin Stob, *Purdue University Agricultural Experiment Station.*

Trial I. Lot treatments in mg. of hormone per lb. of ration, daily gains (lb.), feed per 100 lb. gain (lb.), average backfat depth (mm) and iodine no. of extracted fat were as follows: Lot 1, control, 1.70, 363.3, 39.3, 57.8; Lot 2, 5.0 mg. methyl testosterone, 1.67, 357.8, 36.5, 61.7; Lot 3, 0.6 mg. 9 alpha-fluoro-11 beta hydroxy 17 alpha-methyl testosterone, 1.66, 362.1, 37.5, 59.8; Lot 4, 0.4 mg. 17 ethyl-19 nortestosterone, 1.69, 344.4, 39.1, 57.8; Lot 5, 2.0 mg. 17 ethyl-19 nortestosterone, 1.55, 378.0, 40.1, 59.9; Lot 6, 0.6 mg. 11 beta-hydroxy-17 alpha-methyl testosterone, 1.71, 361.8, 39.1, 57.2. Trial II. Lot treatments (either as mg. hormone per lb. of protein

supplement or mg. hormone per implant), daily gain (lb.), feed per 100 lb. gain (lb.) and live backfat depth (in.) were as follows: Lot 1, control (barrows and gilts), 1.48, 319.7, 1.52; Lot 2, fed 1.0 mg. DES (barrows), 1.57, 312.3, 1.60; Lot 3, fed 1.0 mg. DES (boars castrated on 84th day), 1.47, 309.9, 1.42; Lot 4, fed 1.0 mg. DES and 20.0 mg. MT (barrows and gilts) 1.44, 302.3, 1.45; Lot 5, fed 1.0 mg. DES and implant of 50 mg. testosterone propionate (barrows and gilts), 1.55, 307.6, 1.54; Lot 6, implant of 3.0 mg. DES and 50 mg. TP (barrows and gilts), 1.53, 306.0, 1.49. Trial III. Lot treatments in mg. of 11 beta-hydroxy-17 alpha-methyl testosterone per lb. of ration, daily gains (lb.), feed per 100 lb. gain (lb.) and live backfat depth (in.) were as follows: Lot 1, control, 1.82, 344.3, 1.70; Lot 2, 0.3 mg., 1.72, 332.3, 1.52; Lot 3, 0.6 mg., 1.80, 340.6, 1.65; Lot 4, 0.9 mg. 1.87, 333.4, 1.62; Lot 5, 1.2 mg., 1.81, 335.4, 1.57; Lot 6, 1.8 mg., 1.79, 324.7, 1.65.

110. THE EFFECTS OF SEX AND STILBESTROL ON GROWTH, FEED EFFICIENCY AND CARCASS CHARACTERISTICS OF SWINE. L. F. Tribble, G. L. Amick, J. F. Lasley and S. E. Zobrisky, *University of Missouri.*

A study was made of the effects of the sex and the feeding of stilbestrol on the rate of gain, feed efficiency and carcass characteristics of swine. The lots were as follows: (1) spayed gilts, (2) normal gilts, (3) normal gilts + stilbestrol, (4) spayed gilts + stilbestrol, (5) barrows + stilbestrol, (6) barrows, (7) boars, (8) boars + stilbestrol. Eight pigs were fed in each lot from 44 to 200 lb. All pigs received the same ration except for the addition of stilbestrol, 0.25 mg. per lb. of feed, in one-half of the lots. Four pigs from each lot were slaughtered at 200 lb. for carcass analysis and examination of the reproductive organs. There were no significant differences in rate of gain of the pigs of the various sex conditions or of those fed stilbestrol as compared to those not fed stilbestrol. However, there was a sex-stilbestrol interaction as the males increased and the females decreased in rate of gain when stilbestrol was fed. Stilbestrol had no significant effects on the various carcass characteristics. The carcasses of the boars had less fat and a higher percent of lean cuts than the other groups. The carcasses of the gilts ranked next on percent of fat and lean cuts with barrows and spayed gilts having about the same. The feeding of stilbestrol to boars reduced the size of the testes approximately 33% and the number of sperm in the epididymis 3%.

111. EFFECT OF FEEDING STILBESTROL ON THE METABOLISM OF CALCIUM, PHOSPHORUS AND NITROGEN IN BARROWS AND RATS. M. C. Bell, *UT-AEC Agricultural Research Laboratory.*

Sixty-four weanling male albino rats and eight Yorkshire barrows were used in metabolism trials to study the effects of feeding diethylstilbestrol. The feeding of 100 mcg. of stilbestrol per kilogram of ration to the rats in two balance trials significantly depressed growth rate by 30% and also depressed to a lesser extent the retention of nitrogen. Phosphorus retention was not significantly influenced while calcium retention was reduced ($P<0.05$) by stilbestrol feeding for 14 days. Ca^{45} and P^{32} metabolism paralleled the metabolism of stable calcium and phosphorus. Stilbestrol depressed feed intake but had no influence on the apparent digestibility of nitrogen or dry matter. The feeding of 2 mg. of stilbestrol daily to barrows for 40 days did not influence feed intake, weight gains, nitrogen digestion and retention, or the metabolism of phosphorus. Calcium retention was increased by stilbestrol feeding when the barrows averaged 150 lb. but there was no influence on calcium retention in a second trial when the barrows averaged 200 lb. Stilbestrol feeding had no statistically significant influence on the true digestibility of calcium or phosphorus in either of the two trials. Iodine-131 uptake by the thyroids did not reveal any differences due to treatment.

112. SOME PHYSIOLOGICAL RESPONSES OF THE BOVINE TO CALCIUM ALUMINOGLUCONATE ADMINISTRATION. K. A. Kendall and K. E. Harshbarger, *University of Illinois.*

Levels of minerals in the blood, urine and feces were determined in six non-lactating dairy cows for a 3-hour period prior to the intravenous administration of a 27.3% calcium aluminogluconate solution. Following the injection, the mineral levels and rates of excretion were further studied at 1, 2, 3, 6 and 9 hours. During the first hour following administration, blood serum calcium levels were doubled while inorganic phosphorus levels by the second hour were more than twice that of the beginning levels. The urinary volume during the first hour after administration, on the average, equaled that of the previous 3-hour period. Average total volume of urine for the 3-hour post-administration period was twice that of the preliminary 3-hour period. Even when drinking water was withheld, during the first three hours following administration in one cow, the urine volume rose to four times that of the previous pre-injection 3-hour period. Sharp increases in the levels and quantities of urinary calcium and inorganic phosphorus excreted were observed during the first hour after calcium aluminogluconate administration. Normal levels were observed after 9 hours. The maximum levels of calcium per gram of fecal dry matter were observed at 3 to 6 hours. Total urinary nitrogen excreted remained constant. Trends in blood plasma mineral values were observed in three cows with parturient paresis following calcium aluminogluconate administration were similar to those of the non-lactating cows.

113. EFFECT OF PELLETING AND ANTIBIOTICS ON THE INCIDENCE AND DEVELOPMENT OF URINARY CALCULI IN LAMBS. Joe D. Robbins, Leonard V. Packett, Jr., Earl Whitaker, Thomas D. Watkins, Jr., and H. O. Kunkel, *Texas Agricultural Experiment Station.*

Experiments were conducted to compare two reported calculogenic diets with respect to production of urinary calculi and to evaluate tetracycline antibiotics in retarding the development of the calculi. One hundred and sixty-three wether lambs divided into five lots were fed 98 days on the following ration in pelleted and non-pelleted form: 45% ground milo, 10% cottonseed meal, 10% molasses, 8% ground alfalfa, 27% ground cottonseed hulls. Deaths resulting from urolithiasis were 15.3% of the lambs with a total of 33.7% having urinary calculi in the urinary tract recorded after examination of the tracts at the termination of the experiment. In a second experiment 50 wether lambs divided into five lots were fed for 118 days on a non-pelleted ration of: 24% oat straw, 24% beet pulp, 14% wheat, 16% oats, 18% linseed meal, 4% cane sugar, with 48 lb. K_2HPO_4 added per ton. Twenty-five or 50% had small calculi in their urinary tract at the time of slaughter but no death losses or other gross symptoms of urolithiasis were observed with this diet. There were no significant differences between these rations as to the incidences of urinary calculi. However, the greater number of deaths and the greater extents of calculi development with the milo-cottenseed meal diet were highly significant statistically ($P<0.01$). Oxytetracycline and chlortetracycline did not affect the incidence or the development of calculi with either diet in these experiments, in contrast to the significant reduction noted in earlier experiments (Proc. Soc. Exp. Biol. Med. 97:860, 1958). Pelleting the milo ration significantly increased the incidence and development ($P<0.01$) of urolithiasis.

114. EFFECT OF CHEMICAL AND ENZYMATIC AGENTS ON THE FORMATION OF URINARY CALCULI IN FATTENING STEERS. H. R. Crookshank, F. E. Keating, Earl Burnett, J. H. Jones and R. E. Davis, *U.S.D.A. & Texas Agricultural Experiment Station.*

The addition of ammonium chloride or phosphoric acid to the ration was effective in reducing stone formation in steers fed a fattening ration. Ammonium chloride

appeared to be the more effective. Injections of hyaluronidase at the start and at the mid-point of the feeding period did not affect stone formation, nor did substituting cottonseed hulls for a portion of the silage in the ration have any effect.

115. EFFECT OF SODIUM SILICATE ON THE DEVELOPMENT OF URINARY CALCULI AND THE EXCRETION OF VARIOUS URINARY CONSTITUENTS IN SHEEP. R. J. Emerick, L. B. Embry and O. E. Olson, *South Dakota Agricultural Experiment Station.*

Four groups each of six wether lambs were fed rations containing two sources of roughage, with and without 1% sodium silicate, in an attempt to elucidate factors which are predisposing to the production of urinary calculi. When prairie hay was fed as the source of roughage, three sheep developed urinary calculi. Two of these had received sodium silicate. When the roughage consisted of alfalfa hay, no calculi occurred. When compared with the sheep fed alfalfa hay, those receiving prairie hay in the ration excreted 10 times as much phosphorus and approximately one-half as much magnesium in the urine. The feeding of sodium silicate significantly lowered urinary calcium excretion when fed in a ration containing prairie hay and magnesium excretion when the ration contained alfalfa hay. Sodium silicate feeding and subsequent silica excretion did not appear to be disposing factors for the production of calculi. A correlation was observed, however, between urinary phosphorus levels and calculi production. An average of 125 mg. of phosphorus per day was excreted by the calculi-developing lambs while the calculi-free lambs receiving the same rations excreted an average of only 19 mg. per day. This correlation existed regardless of the type of calculi formed.

116. NORMAL LEVELS OF HEMOGLOBIN, HEMATOCRIT, CALCIUM, PHOSPHORUS, AND SOME MICRO-ELEMENTS IN THE BLOOD OF FLORIDA BEEF CATTLE. G. K. Davis, J. T. McCall and W. G. Kirk, *University of Florida.*

During the past 15 years blood samples have been collected from Florida beef and dairy cattle which have been under conditions ranging from growing to fattening and on soils ranging from sand to muck land. Samples taken from the same animals at four different times during the year for a ten-year period did not show any seasonal variation. Average values for hemoglobin, hematocrit, calcium and phosphorus were 10.7, 46.0, 10.8 and 4.6, respectively. Serum copper values ranged from 0.60 to 1.6 p.p.m. Vitamin A values ranged from 200 to 300 U. S. P. units per 100 ml. of plasma and carotene values from 0.50 to 1.1 mg. per 100 ml. plasma.

117. THE OCCURRENCE AND ALLEVIATION OF ANEMIA IN YOUNG CALVES. J. W. Hibbs, H. R. Conrad and J. H. Vandersall, *Ohio Agricultural Experiment Station.*

Calves fed high roughage diets either pelleted or with loose hay usually maintained a relatively high hemoglobin level (10.5–11.5%). However, in one batch of high roughage pellets severe anemia developed after the 7-week milk feeding period. The high roughage pellets fed to these calves consisted of 2 parts of ½ in. ground dehydrated alfalfa, third cutting, and 1 part grain (corn 69%, oats 30.1% and salt 0.9%). Total protein was low, 13.3%. The anemia was associated with a normal blood picture except that cell volume was low. The Fe and Cu contents of the alfalfa were normal and the oral administration of $FeCl_3$ $FeNH_3$ citrate, $CuSO_4$ and $CoCl_2$ did not raise the hemoglobin levels in the post-milking feeding period. Either low Fe absorption perhaps due to excessively high pH in the upper duodenum or possibly the interference with normal hemopoiesis resulting from low protein intake may have caused the anemia. When these pellets were fed, two or three 10 ml.

injections of iron dextran (Armidextran–50 mg. Fe/ml.) given at 10–14 day intervals were required to prevent recurrence of anemia. Anemia was observed in a number of newborn calves, which was not related to the hemoglobin level of the dams. This indicated a prenatal problem which usually corrected itself soon after roughage eating began. Recovery was hastened either by oral $FeCl_3$ or by a single 10 ml. injection of iron dextran.

118. EFFECT OF DIETARY COPPER LEVEL AND THE INTAKE OF OTHER MINERALS ON THE LIVER COPPER CONCENTRATION OF THE CALF. W A. Hardison, R. F. Miller, N. O. Price and R. F. Kelly, *Virginia Agricultural Experiment Station.*

Twenty-four Holstein bull calves were fed from 2 days of age a basal ration of whole milk, concentrates containing approximately 4 ppm. Cu and hay averaging 4 to 5 ppm. Cu. The treatment groups were as follows: (1) basal plus Ca, P, Mn, Co, Zn, Fe and Cu; (2) same as (1) except no added Cu; (3) basal plus Cu only; (4) basal. All groups received iodized salt. Av. daily Cu intake per calf (excluding that in the milk) was 17.2, 6.8, 16.5 and 6.8 mg. for groups 1, 2, 3 and 4, respectively. All calves were slaughtered between 3 and 7 months of age, at which time liver samples were collected for Cu analysis. Mean liver copper concentrations obtained were as follows: (1) 333.2 $\pm$ 57.0 ppm; (2) 105.4 $\pm$ 11.9 ppm; (3) 364.3 $\pm$ 48.6 ppm; (4) 166.1 $\pm$ 26.4 ppm. The feeding of low levels of Cu significantly reduced ($P<1\%$) the liver Cu content (groups 1 and 3 vs. groups 2 and 4). Furthermore, at low levels of Cu intake the presence of other minerals in the ration significantly decreased ($P<5\%$) the concentration of Cu in the liver (group 2 vs. group 4). Additional work with the rat indicates that the depression of liver Cu observed in group 2 may have been due to the presence of added Ca and/or P.

119. SOME EFFECTS OF FEEDING VARIOUS LEVELS OF FLUORINE TO BEEF COWS FOR A TEN-YEAR PERIOD. C. S. Hobbs, G. M. Merriman, R. P. Moorman and L. Hardin, *University of Tennessee.*

Beef cows have been individually fed varying levels (control level and control level + 10, 20, 30, 40, 50, 70, 100 ppm., and 100 ppm. F plus defluorophos) of fluorine from sodium fluoride for more than 10 years to determine the physiological effects of fluorine. Similar cattle were put on pastures which had fluorine content high for the area and others in barn were fed hay cut from these areas. The occurrence and degree of fluorosis in cattle has been found to depend upon many factors, including: (1) the level of fluorine ingested; (2) the age of the animal and the stage of tooth development (of major importance in dental fluorosis); (3) the length of time that an increased level of fluorine is ingested; (4) the initial fluorine stored in the animal's body; and (5) the solubility and availability of the fluorine-bearing material ingested. The lowest level of fluorine as sodium fluoride that caused a significant decrease in feed consumption was 48 ppm. of fluorine in the total dry ration of barn-fed cattle, or 1.027 mg. of fluorine daily per kilogram of body weight. This decrease in feed consumption did not occur until the cows had been on test 2½ years. There was no significant decrease in feed consumption between pasture groups up to 45 ppm. F. The effects on feed consumption, weight gains, reproduction, calf production, F content of rib, teeth, and digestion were determined.

120. THE EXPERIMENTAL PRODUCTION OF HYPOMAGNESEMIC TETANY IN CATTLE. E. C. Lefiel, K. R. Mason and J. C. Shaw, *University of Maryland.*

Hypomagnesemic tetany in parturient cows on winter rations is a serious problem on many farms in Western Maryland and surrounding areas. Six cows (three

beef and three dairy), in a herd and area with no history of tetany, were fed hay from an affected farm as the sole ration for 4 to 6 months prepartum and in early lactation. Average serum magnesiums (mg. per 100 ml.) were 1.1 at 4–6 weeks prepartum, 0.6 at parturition, 0.7 at 2 weeks postpartum. The three beef cows developed typical symptoms of grass tetany during the first 2 weeks after calving. Analysis of samples obtained by biopsy showed bone magnesium to be 50% of normal. Affected cows were both hypocalcemic and hypomagnesemic when tetany developed and responded to calcium-magnesium therapy but not to magnesium alone. The dairy cows developed hypomagnesemia but exhibited no symptoms of tetany. The hay contained approximately .08% magnesium and 8.0% protein and was not consumed in sufficient amount to prevent loss in body weight. These results suggest that the winter tetany observed in beef cows in the southern Appalachian region is a hypomagnesemic tetany of nutritional origin. The hay fed was the only factor common to the feed lot where the tetany was reproduced and the farm which had a high incidence of winter tetany.

121. SOME INTERRELATIONSHIPS BETWEEN MAGNESIUM AND TOCOPHEROL IN THE DAIRY CALF. B. A. Dehority, J. E. Rousseau, Jr., H. D. Eaton, C. F. Helmboldt, G. S. Myers, Jr., A. P. Grifo, Jr., Martha W. Dicks, D. G. Hazzard, J. F. Sykes and L. A. Moore, *Storrs (Conn.) Agricultural Experiment Station and U. S. Dept. of Agriculture.*

Forty-eight male Guernsey calves, approximately 7 days old, were fed a basal ration of whole milk plus required minerals, except magnesium, vitamins A and D, and chlortetracycline. Added per 100 lb. live wgt./day to this ration, separately and in all possible combinations (2^3 factorial design), were magnesium (Mg), at 2.5 g.; d,l-a-tocopheryl acetate (Toco), 200 mg.; and cod liver oil (CLO), 1 oz. In anticipation of high mortality, eight calves were fed the basal ration, 12 the basal plus CLO, and eight the basal plus mg. plus CLO; in contrast to only four calves on the other treatments. Mortality was high in the latter two groups and the results are based upon four calves per treatment group. The mean serum differences, at $P \leq 0.05$ and based on av. values obtained from monthly samples during a 28 wk. expt. period, were for *Mg.*: (in mg./100 ml.) calcium (−0.23), phosphorus (+0.95), magnesium (+0.69), sodium (−2), cholesterol (+25), (in γ/100 ml.) carotenoids (+10), vitamin A (−2); for *Toco:* potassium (−0.6 mg./100 ml.), tocopherol (+590 γ/100 ml.); and for *CLO:* (in mg./100 ml.) phosphorus (+0.38), magnesium (−0.28), sodium (+2), potassium (+0.7), (in γ/100 ml.) carotenoids (−26), vitamin A (+5). In terminal measurements of whole blood Hb, whole blood ammonia, and whole blood urea, only the latter was affected as follows: *Toco* (−1.3 mg. urea N/100 ml.) and *CLO* (+0.9 mg. urea N/100 ml.). Differences in growth increases were: live weight—*Toco* (+24 lb.).

122. SELENIUM, VITAMIN E AND LINSEED OIL MEAL AS PREVENTATIVES OF MUSCULAR DYSTROPHY IN LAMBS. J. F. Proctor, D. E. Hogue and R. G. Warner, *Cornell University.*

Previous work at this station has shown that ewes receiving a concentrate mix of corn, oats, wheat bran, and linseed oil meal seldom produce lambs with muscular dystrophy. In addition, it has been indicated that factors other than tocopherol are involved in preventing muscular dystrophy in lambs. A known dystrophogenic ration of mixed trefoil-grass hay and raw cull kidney beans was fed to 64 grade, pregnant ewes during the fall and winter of 1957–58. One month prepartum, the ewes were divided into four groups as follows: (1) control group receiving the hay and bean basal, (2) basal ration plus 0.25 lb. linseed oil meal per head per day substituted for an equal amount of beans, (3) basal ration plus 1 ppm. selenium as Na_2SeO_3, and (4) basal ration plus 100 I.U. alphatocopheryl acetate per head per

day. The additives were supplied in cerelose as the carrier and 1 lb. given to each group daily. The ewes in the control group and treatment lot number 2 were given a similar amount of plain cerelose. The incidence of diagnosed muscular dystrophy in the lambs in the 4 lots was 8 of 18, 2 of 14, 1 of 21, and 2 of 15, respectively. Selenium assay (Oak Ridge, neutron activitation analysis) of the feeds in parts per million was as follows: mixed trefoil-grass hay, 0.062; kidney beans, 0.011; and linseed oil meal, 1.18. From this study it appears that selenium is a factor in the prevention of nutritional muscular dystrophy in lambs. Additional studies will be conducted.

123. THE EFFECTIVENESS OF ARSANILIC ACID IN COUNTERACTING SELENIUM POISONING IN BEEF CATTLE. J. A. Minyard, C. A. Dinkel and O. E. Olson, *South Dakota State College.*

Three trials, two feed-lot and one summer grazing, were conducted to study the effectiveness of arsanilic acid in counteracting selenium poisoning in beef cattle. In trial I, 60 weaning calves were allotted to three treatments, two lots per treatment (1) no arsanilic acid; (2) 0.005% arsanilic acid; (3) 0.01% arsanilic acid). All calves were fed prairie hay free-choice containing 5.4 to 7.1 ppm. of naturally occurring selenium. Daily gains for the 168 day trial were 0.71, 0.67 and 0.72 lb., respectively. The differences between treatments were not significant. No protective effect of arsanilic acid on visible symptoms was noted. In trial II, 39 steer and heifer calves from trial I were continued on the same arsanilic acid supplements for 151 days through the summer grazing season. The calves were carried on seleniferous range. The average daily gains for the summer grazing period were 0.98, 1.15 and 1.23 lb., respectively. These differences were highly significant. The number of calves in the control group exhibiting visible symptoms of selenium poisoning increased during the summer. The number of calves showing symptoms in the two groups receiving arsanilic acid either decreased or remained unchanged. In trial III, 24 heifer and 11 steer weaning calves were allotted to three treatments (1) pre-mixed growing fattening basal ration; (2) basal ration plus 12 ppm. selenium; (3) basal ration plus 12 ppm. selenium and 0.01% arsanilic acid). The trial was continued for 139 days. Average daily gains were 1.84, 1.48 and 1.63 lb., respectively. The differences between treatments were not significant. Visible selenium symptoms decreased rapidly in the control group, increased in the group fed selenium and decreased in the group fed selenium and arsanilic acid, indicating some protective effect of arsanilic acid.

124. INTERRELATIONSHIPS BETWEEN DRIED CORN DISTILLERS' SOLUBLES AND CERTAIN MINERALS IN THE PREVENTION OF PARAKERATOSIS IN SWINE. J. C. Robertson and C. E. Barnhart, *University of Kentucky.*

In three trials, 132 pigs were used to study the occurrence of parakeratosis in pigs fed rations varying in levels of calcium and to determine the value of distillers' solubles and zinc as a preventive or cure for the disease. The feeding of purified rations to pigs confined to metal metabolism crates containing levels of calcium up to 1.30% produced good rates of gain and feed conversion with no symptoms of parakeratosis. The feeding of a corn-soybean meal ration with the calcium level at 0.50% resulted in good growth. This ration containing 1.35% calcium resulted in poor growth and 50% parakeratosis. The addition of 5% distillers' solubles did not improve growth. Forty percent of these pigs developed parakeratosis. Adding zinc to this high calcium ration at a level of 130 ppm. prevented parakeratosis and improved growth. Distillers' solubles improved growth rate of those pigs on low calcium or high calcium supplemented with zinc. Where symptoms of parakeratosis were present, zinc supplementation resulted in increased growth rate and alleviation of symptoms.

125. EFFECT OF ORGANIC AND INORGANIC SOURCES OF UNIDENTIFIED GROWTH FACTORS ON THE GROWING PIG. D. L. Jeter, J. H. Conrad and W. M. Beeson, *Purdue University Agricultural Experiment Station.*

A total of 196 three-week-old pigs were used in a series of four experiments to study the response of the growing pig to unidentified growth factors when fed a semi-purified diet. In experiment 1, 5% levels of distillers dried solubles (DDS), brewers dried yeast (BDY), dried whey or Lassen process fish solubles increased gains from 1.2 to 9.7% in the absence of an antibiotic but when 25 mg. of crystalline chlortetracycline HCl was added per lb. of diet, the response varied from a 6.6% decrease to an 8.5% increase in gains. Antibiotic-fed pigs on the average gained significantly more than pigs fed no antibiotic. In experiment 2, the addition of 5% DDS, ash DDS, reconstituted ash DDS, 5% BDY, ash BDY or 1 ppm. Se to a basal containing 18 ppm. Zn increased gains but failed to prevent parakeratosis (PK). The addition of 50 ppm. Zn to the basal completely prevented PK and significantly increased the growth rate over all other treatments. In experiment 3, the addition of 5% DDS to a basal containing 50 ppm. added Zn increased growth rate 14% and feed efficiency 12%. However, the addition of the ash of DDS, 5% BDY and ash of BDY did not increase growth rate but increased feed efficiency 10.3%, 9.5% and 6%, respectively. Three ppm. Se depressed feed consumption and gains. Twenty-four ppm. strontium depressed gains 8% but increased feed efficiency 5.2%. Five percent DDS, ash of DDS, and 5% BDY decreased the incidence of crooked legs. In experiment 4, three-week-old pigs were depleted two weeks on the basal diet. Preliminary results indicate the unidentified factor(s) in DDS are partially extractable with 95% methanol.

126. SERUM ALKALINE PHOSPHATASE AS AFFECTED BY DIETARY CALCIUM AND ZINC LEVELS IN SWINE. R. W. Luecke, D. A. Schmidt and J. A. Hoefer, *Michigan State University.*

The purpose of the present investigation was to study the effects of various levels of dietary calcium both with and without supplemental zinc on blood serum levels of alkaline phosphatase and lactic dehydrogenase. Accordingly, 60 weanling pigs were divided equally among six experimental treatments which consisted of the following: (1) High Ca, (2) high Ca + chlortetracycline, (3) high Ca + Zn, (4) high Ca + chlortetracycline + Zn, (5) low Ca, (6) low Ca + Zn. By the eighth experimental week virtually all of the pigs in lots 1, 2 and 5 had developed parakeratosis. All of the animals were then bled and the following average values for serum alkaline phosphatase (Bessey-Lowry units) were found: (1) 0.73 $\pm$ 0.09, (2) 0.66 $\pm$ 0.11, (3) 3.50 $\pm$ 0.29, (4) 5.15 $\pm$ 0.46, (5) 0.54 $\pm$ 0.10, (6) 3.26 $\pm$ 0.33. Following this the pigs in lots 1, 2 and 5 were fed 100 ppm. of supplementary Zn for a period of two weeks and bled again. The following average values for serum alkaline phosphatase (Bessey-Lowry units) were found: (1) 2.81 $\pm$ 0.26, (2) 2.63 $\pm$ 0.23, (5) 3.24 $\pm$ 0.15. Zinc supplementation produced a significant increase in serum alkaline phosphatase values. Concurrent studies with lactic dehydrogenase indicated that supplemental Zn had no effect on the activity of this enzyne. Additional studies on the total Zn content of blood serum revealed that Zn supplementation produced very large increases in total serum Zn.

127. EFFECT OF ZINC AND CALCIUM LEVELS OF THE DIET ON ZINC EXCRETION BY THE ALBINO RATS. R. M. Forbes and Martha Yohe, *University of Illinois.*

In view of the demonstrated exaggeration of zinc deficiency by calcium noted in practical feeding of pigs and the balance data of Beardsley and Forbes which showed a 17% increase in urinary zinc excretion as a result of increasing calcium in the diet

of young pigs, the following experiment was undertaken. Twenty-four weanling albino rats were placed in appropriate cages and individually fed for 6 weeks a casein-glucose diet containing 0, 10, 20 or 40 ppm. of added zinc. Half of the rats on each zinc level received double the basal amount of calcium. During the second and sixth weeks of feeding, collection of urine and feces were made. Weight gains of rats receiving the basal level of zinc were less than those receiving supplemental levels. Balance data revealed that as zinc level increased, total zinc excretion increased as a percent of the intake, while urine zinc excretion remained constant in absolute terms. The presence of additional calcium did not influence zinc excretion or weight gains. There was a tendency for rats on higher levels of zinc to excrete a larger proportion of the intake during the first than during the second collection period.

128. ZINC TOXICOSIS IN THE WEANLING PIG. M. F. Brink, D. E. Becker, S. W. Terrill and A. H. Jensen, *University of Illinois.*

Ninety-two weanling pigs were used to determine the zinc tolerance and the manifestations of zinc toxicosis. Levels of zinc, added as reagent grade zinc carbonate, ranging up to 0.8% of the diet were fed for 42 days. Corn-soybean oil meal diets were used. The addition of 0.2% zinc to the diet was the maximum level tolerated. Higher levels produced symptoms of zinc toxicosis. Toxicity was characterized by a depressed rate and efficiency of gain, and a lower feed intake. In addition, arthritis, extensive hemorrhage in the axillary space, gastritis, catarrhal enteritis, congestion of the mesentery, and hemorrhages in the ventricles of the brain, lymph nodes and spleen were observed. Feeding high levels of zinc frequently caused death within 21 days on treatment. Hemoglobin values, determined on the 21st day of the experiment, were unaffected by the levels of zinc fed. Calcium added at 1% of the diet as dicalcium phosphate had no effect upon the level of zinc tolerance or upon the toxic reactions.

129. THE ZINC REQUIREMENT OF GROWING PIGS. W. H. Smith, M. P. Plumlee and W. M. Beeson, *Purdue University Agricultural Experiment Station.*

A semi-purified basal ration containing 20% protein, 0.66% Ca, 0.47% P and 16 ppm. Zn was used in these studies. In the first experiment 42 pigs with an initial weight of 10.5 lb. were fed rations containing 16, 21, 26, 31, 36, 41 or 46 ppm. of total Zn for 8 weeks. Daily gains were 0.06, 0.13, 0.25, 0.52, 0.61, 0.69 and 0.76 lb., respectively, for the 16 through 46 ppm. Zn lots. The increase was linear. The first difference in growth rate occurred in the pigs on the basal ration during the third week on experiment. Parakeratotic lesions were observed in all groups receiving 16 to 36 ppm. of Zn. The severity of the lesions was in inverse proportion to the Zn content of the ration. Two pigs on the basal ration died from parakeratosis. Feed required per lb. of gain was 13.9, 6.5, 4.1, 2.4, 2.3, 2.2 and 2.1 lb., respectively, for the 16 through 46 ppm. Zn lots. At the end of 8 weeks, all parakeratotic pigs were divided into groups of four each and fed the basal ration plus the following treatments: Zn, 50 ppm.; citric acid, 1%; benadryl, 12.5 mg./lb.; thiamine, 12 mg./lb.; Na formate and acetic acid, 1%; and Na acetate and acetic acid, 1%. Appetite, growth rate and the appearance of the skin were markedly improved by the addition of 50 ppm. of Zn. The other treatments were ineffective. In experiment II 3-week-old pigs were fed the same basal ration used in experiment I. Zn oxide was added to supply 36, 41, 46, 51, 56 and 61 ppm. of total Zn. At the end of 5 weeks, the data show a reduction in growth on the 36 ppm. Zn level.

130. THE EFFECT OF FEEDING ZINC, IRON, AND COPPER TO PIGS FROM WEANING TO MARKET WEIGHT. J. A. Hoefer, D. E. Ullrey, E. R. Miller, R. W. Luecke and H. D. Ritchie, *Michigan State University.*

Fifty weanling pigs in five lots were used to compare the effects of adding certain trace minerals—zinc (50 ppm.) iron (100 ppm.) and copper (125 ppm.)—to a con-

trol ration which supplied calcium at a level (0.5%) slightly lower than National Research Council recommendations. Zinc and iron were also combined in one treatment. Hemoglobin, hematocrit and serum alkaline phosphatase determination were carried out. Daily gains for the control, zinc-, iron-, zinc-and-iron-, and copper-fed pigs were 1.01, 1.49, 1.32, 1.18 and 1.49 lb., respectively. The pigs on the control diet and those receiving the combination of iron and zinc were quite variable in growth in contrast with the rather uniform growth of the pigs receiving zinc and copper. The incidence of parakeratosis for the five lots was 60, 0, 10, 0 and 0 %, respectively. The dermatosis was most severe in the control lot during the 6th to 8th week and tended to decrease in severity thereafter. Associated with the decline in parakeratosis was an increase in feed intake and daily gain. There were no apparent differences in hemoglobin and hematocrit values between the various treatments, but the serum alkaline phosphatase values were significantly higher for those lots receiving zinc.

131. THE EFFECT OF ORAL VERSUS INJECTABLE IRON ON HEMOGLOBIN, HEMATOCRIT AND WEIGHT GAINS OF BABY PIGS. J. H. Maner, W. G. Pond, and J. K. Loosli, *Cornell University*.

A preliminary study showed no increase in rate of gain, hemoglobin or hematocrit of pigs injected intramusculary at 3 days of age with 2 ml. of iron-dextran over littermate controls when the udders of their dams were sprayed daily with a ferrous sulfate solution. In a subsequent study 171 baby pigs were used to compare the effect of one injection of iron-dextran, two injections of iron-dextran, and daily spraying of the sows udder with a solution of ferrous sulfate in preventing anemia. No significant differences in weight gains were recorded at 24 days of age between daily spraying of the sow's udder and 2 ml. of iron-dextran injected at 3 and 10 days of age. However, one 2-ml. injection at 3 days of age produced significantly ($P<0.05$) slower weight gains, and significantly lower hemoglobin and hematocrit values than when either two injections or oral iron were given. The average daily gains for pigs receiving one injection, two injections, and oral iron were 0.38, 0.41, and 0.41 lb., respectively. Corresponding values for hemoglobin were 9.12, 9.82, and 9.72 gm. % and for hematocrit, 29.4, 31.6, and 32.3%. These data indicate that one iron-dextran injection (100 mg.) may not always be adequate for suckling pigs. When iron-cobalt-copper pills were given weekly, equal growth but lower hematocrit and hemoglobin values were obtained at 3 weeks when compared to animals given one or two injections. All of this work involved pigs born and raised in concrete dry lot. Pigs were given access to creep feed when approximately 3 weeks old, but consumption was negligible during the first few days.

132. THE ORAL IRON REQUIREMENT OF THE BABY PIG. D. E. Ullrey, E. R. Miller, D. A. Schmidt, E. D. Purkhiser, J. A. Hoefer and R. W. Luecke, *Michigan State University*.

Two trials have been conducted to determine the dietary iron requirement of the baby pig. Week-old pigs were taken from the sow and fed a 20% solids, synthetic milk, containing no added iron, for 4 days. They were then allotted at random from litter and weight outcome groups to the various treatments. During the first trial, the pigs were individually fed a synthetic milk supplemented with 0, 10, or 100 ppm. of ferrous iron ($FeSO_4 \cdot H_2O$). During the second trial, milk supplemented with 0, 50, 100, or 200 ppm. of ferrous iron was provided. The experimental diets were fed for 40 days in both trials. Extensive hematological examinations of the formed elements were made weekly on all pigs. Iron balance studies were performed; liver, kidney, spleen and muscle were assayed for tissue iron storage; and gross and microscopic post mortem examinations were made on a number of animals during the first trial. Maximum rate of gain, feed efficiency, and serum iron concentration were obtained in those pigs supplemented with either 100 or 200 ppm. of iron. Optimum hematological values were also obtained at these levels. With the exception of the spleen, the

organs removed from pigs receiving 100 ppm. of supplemental iron contained the highest concentration of this element, while pigs supplemented with 0 or 10 ppm. did not differ significantly. Of the iron ingested, apparent absorption was 82%, 72%, and 50% in those pigs supplemented with 0, 10, or 100 ppm. of iron, respectively.

133. PERFORMANCE OF AND BLOOD STUDIES ON STEERS FED A PURIFIED TYPE RATION. Ronald R. Johnson, Orville G. Bentley, A. L. Moxon and E. W. Klosterman, *Ohio Agricultural Experiment Station.*

The objective of these studies was to develop a purified-type ration for studying the nutrition of growing steers. In a preliminary experiment, steers were fed a ration of cellulose, starch, corn sugar, corn gluten meal, urea and minerals together with mixed hay for 70 days. Although the animals consumed up to 12 lb. of the ration per day, they lost weight during the experimental period. The addition of 2 or 4% corn oil did not increase feed consumption but improved the texture of the ration. Corn sugar enhanced the palatability of the ration. The type and amount of roughage fed with the purified ration influenced feed intake. In a second experiment, 14 steers were started on a purified-type basal ration consisting of cellulose 40; starch, 24; corn sugar, 20; purified soya protein, 11; minerals and vitamins A and D and in addition 3 lb. of chopped poor quality timothy hay per day. Variations in the ration throughout the experimental periods included substitution of urea for purified soya protein (up to 100% of the N), addition of molasses, alfalfa meal, corn steep liquor, lower proportion of cellulose in the ration, and different K and Mg levels. In six trials lasting 21–42 days animals gained from 0.31 lb. to 1.70 lb. per day. In two trials using a 40% cellulose ration the animals gained 0.66 lb./day while in four trials using a 30% cellulose ration the animals gained 1.23 lb./day. Doubling the Mg level or using five times the K level in the basal ration appeared to have little effect on daily gains. Some of the best gains were on rations in which urea formed at least ¾ of the nitrogen. Clean wheat straw appeared to be as good a source of roughage as the poor quality timothy hay. Blood analysis indicated that hemoglobin, hemotocrit, serum protein, and six minerals were within normal ranges.

134. LEVELS OF VARIOUS BLOOD COMPONENTS IN CATTLE GRAZING ALFALFA PASTURE AND THEIR POSSIBLE RELATIONSHIP TO BLOAT. L. R. Brown, R. S. Allen, R. H. Johnson, N. L. Jacobson and P. G. Homeyer, *Iowa State College.*

Blood samples were taken from the jugular veins of cattle grazing alfalfa pasture. A total of 34 animals were sampled at least once when not bloated; 41 samples were taken from the same animals during cases of moderate to severe bloat. Whole blood was analyzed for ammonia and total phosphorus (P), and the plasma for trichloroacetic acid (TCA) insoluble P and inorganic P. Limited observations also were made on blood urea and blood pigments. Although bloated animals had average blood values of 0.38 mg. % NH_3–N as compared to 0.30 mg. % NH_3–N for the non-bloated animals, variability was so great that there was no apparent relationship between bloat and blood ammonia levels. During a period when the animals were not bloating the effect of grazing on blood ammonia levels was measured. Initially the level was low, increased to a peak during the grazing period, then decreased subsequent to grazing. Average blood P levels (mg. %) found for bloated and non-bloated animals, respectively, were total blood P, 23.3 and 21.8; plasma TCA insoluble P, 7.21 and 6.12; and plasma inorganic P, 9.35 and 7.73. The mean values for plasma TCA insoluble P and inorganic P for bloat-susceptible animals (when not bloated) tended to be higher than those observed in animals that seldom bloated.

135. STUDIES OF THE INHIBITION OF PASTURE BLOAT WITH DRINKING WATER ADDITIVES. G. E. Mitchell, Jr., R. L. Deininger, T. R. Greathouse, W. W. Albert and A. L. Neumann, *University of Illinois.*

A 10-acre experimental pasture was seeded to a mixture of alfalfa, red clover, and ladino clover. After the legumes attained a height of about 10 in. (May 16) the pasture was divided into four 2½-acre plots and five steers were placed in each plot. Steers were allotted according to weight without regard to previous bloat history. The steers were restrained at night and allowed to graze only between 7:30 a.m. and 6:00 p.m. Observations for bloat were made at 11:00 a.m. and 4:00 p.m. and recorded on a 0 to 10 scale with 0 representing no sign of bloat and 10 representing death due to bloat. After grass and weeds had been grazed from the fence rows, steers bloated regularly on all four plots. Groups of steers were randomly assigned to treatments and plots. Drinking water treatments were: Group 1, no additive; Group 2, 0.1% crude lecithin; Group 3, 0.67% emulsified crude soybean oil; and Group 4, 0.67% emulsified crude soybean oil concentrate. Pounds of experimental material consumed daily per head, gallons of water consumed daily per 100 lb. bodyweight, average individual bloat scores for 34 days, and average daily gains were: Group 1, 0, .86, 3.01 and 1.46; Group 2, .05, 1.29, 3.32 and 1.40; Group 3, .29, .94, 2.55 and 1.69; and Group 4, .35, 1.09, 2.51 and 1.06. The only death attributed to bloat occurred in Group 4.

136. USE OF THE ARTIFICIAL RUMEN TECHNIQUE TO ESTIMATE THE NUTRITIVE VALUE OF FORAGES. Truman V. Hershberger, Theodore A. Long, E. W. Hartsook and R. W. Swift, *Pennsylvania State University.*

The quantitative relationship between cellulose digestion *in vitro* and *in vivo* for 35 forages ($r = 0.97$) has been reported. (North Atlantic Sectional Meeting of the American Society of Animal Production, Rutgers University, 1958). Using the same forages, the digestibility of cellulose *in vitro* by ovine rumen microorganisms was compared with the digestible energy obtained by conventional digestion trials with sheep. A correlation coefficient of 0.92 indicates a highly significant relationship between cellulose digestion *in vitro* and digestible energy. From the data obtained, the following equation was calculated for estimating the digestible energy of a forage, in Calories per kilogram dry matter, from the percent cellulose digested in the artificial rumen in 24 hours: $Y = 1185.5 + 29.81\ X$. Using this equation, the standard deviation of Y from regression is 125.2 with a coefficient of variation of 4.20%.

137. RELATION OF COMPOSITION OF ENERGY SOURCE TO UREA UTILIZATION BY RUMEN MICROORGANISMS. R. A. Bloomfield, M. E. Muhrer and W. H. Pfander, *University of Missouri.*

The purpose of this investigation was to determine the relationship between molecular structure of the energy source and urea utilization by rumen microorganisms *in vitro*. Flasks were incubated for 18 hours and contained 20 ml. rumen fluid, 5 ml. mineral solution, 34 mg. urea, 450 mg. $NaHCO_3$, and 0.1–1.0 g. substrate. Some of the substrates compared were valeric acid, succinic acid, propionic acid, lactic acid, pyruvic acid and alanine. It was found that only the latter three compounds stimulated urea utilization, indicating a possible necessity for a functional group on the alpha carbon. Starch was more active than simple sugars. Fructose was superior to other hexoses. Equal amounts of glucose and fructose (46%), i.e., (46% of the urea utilized) were superior to the similar amount of sucrose (35%). Lactose was consistently inferior. The addition of an equal amount of starch to each of the other carbohydrates caused an increased urea utilization, but only fructose plus starch gave an increase over a similar amount of either starch or fructose. A difference was also found in the type of starch used; corn starch (98%), wheat starch (81%), potato starch (63%) and

soluble starch (55%). It appears that the composition of starch, perhaps the amylose to amylopectin ratio, affects urea utilization by rumen microorganisms.

138. EFFECTS OF CHELATING AGENTS ON CELLULOSE DIGESTION *IN VITRO* BY RUMEN MICROORGANISMS. Oran Little, Edmund Cheng and Wise Burroughs, *Iowa State College.*

Chelating agents offer a tool in studying trace mineral requirements of rumen microorganisms and their importance in ruminant nutrition. *In vitro* studies have indicated that a balanced mineral nutrient solution is needed by rumen microorganisms for optimum cellulose digestion. However, previous work failed to show quantitative requirements for individual trace minerals. In this investigation a chelating agent, ethylenediamine tetra acetic acid (EDTA) was added to a trace-mineral free basal medium and the effects of additions of individual trace minerals were studied. It was found that the addition of iron at a level of 0.5 ppm. increased cellulose digestion and that the increase reached a maximum at a concentration of 12.5 ppm. The addition of 7.5 ppm. of zinc or manganese, or 15.0 ppm. of magnesium also increased cellulose digestion but to a lesser extent than could be obtained with the addition of iron. Cobalt and copper failed to increase cellulose digestion at any concentrations tested but were inhibitory to cellulose digestion at levels of 2.5 ppm. and above. However, part of the inhibitory effect could be counteracted by the addition of EDTA. When selenium was added to the basal medium at a level of 0.3 ppm. or higher, cellulose digestion decreased. This inhibitory effect could not be counteracted by EDTA but was partially removed by the addition of iron. An intricate balance of different trace minerals in supporting cellulose digestion by rumen microorganisms is indicated.

139. SOME CHARACTERISTICS OF THE HEMICELLULOLYTIC ACTIVITY OF RUMEN MICROORGANISMS. R. L. Salsbury, Patricia Elliott and R. W. Luecke, *Michigan State University.*

Enzyme preparations were obtained from the fluid portion of rumen ingesta by adding toluene, treating in a Waring blendor at pH 8.3 and then centrifuging at 25,000 x G. The preparations so obtained showed greatest activity with forage hemicelluloses as substrates, intermediate activity with carboxymethylcellulose, and only slight activity with solid cellulose preparations. A preparation obtained from rumen protozoa showed a similar range of activities when tested against these substrates. Experiments with crude fractions of rumen fluid suggest that much of the hemicellulolytic activity (measured with carboxymethylcellulose as substrate), obtained from the fluid portion of rumen ingesta by the method described, is derived from the protozoa. Cellulose (Solka-Floc) digestion by rumen microorganisms *in vitro* was not increased by the addition of such an enzyme preparation, nor was there an appreciable increase in the susceptibility of wheat straw cellulose after pre-incubation of the wheat straw with the enzyme preparation.

140. COMPARISON OF CELLULOSE DIGESTION *IN VITRO* AND *IN VIVO*. C. F. LeFevre and L. D. Kamstra, *South Dakota State College.*

In a comparison of cellulose digestion coefficients obtained *in vitro* and *in vivo* with 22 different rations, the 48-hour *in vitro* fermentation period most nearly simulated the *in vivo* cellulose digestion. The rations were of several types, rations high and low in roughage, rations with additives such as penicillin, a chemobiotic (Dynafac), and dried rumen product; also, alfalfa silage rations with various preservatives.

Percent cellulose digestion *in vitro* with sheep rumen fluid and steer rumen fluid was compared. When the 22 rations were used, the correlation between the two sources of rumen fluid was statistically significant ($P<0.01$), indicating little difference in cellulose digestion *in vitro* between the innoculum from sheep or steers.

However, when the animals used as sources of rumen fluid were on different rations, the cellulose digestion values *in vitro,* with the same basal media, were of different magnitudes. Greater cellulose digestion was indicated for rations high in roughage both *in vitro* and *in vivo.*

141. AVAILABILITY OF DIFFERENT SULFUR SOURCES FOR RUMEN MICROORGANISMS IN *IN VITRO* CELLULOSE DIGESTION. Allen Trenkle, Edmund Cheng and Wise Burroughs, *Iowa State College.*

It has been established that a source of sulfur is required by rumen microorganisms for cellulose digestion *in vitro.* It has yet to be determined whether different sources of sulfur will completely meet the total requirements of rumen microorganisms. By incubating washed suspensions of rumen microorganisms in a synthetic sulfur-free medium, the value of several sulfur-containing compounds in increasing cellulose digestion was tested. It was found that in the fermentation medium a minimum of 10 to 20 ppm. of sulfur in the form of sodium sulfate was required in promoting optimum cellulose digestion. The microorganisms tolerated up to 200 ppm. of sulfur from sulfate without an inhibitory effect. On the other hand, 15 ppm. of sulfur from sodium sulfite met the needs of rumen microorganisms but 30 ppm. and higher levels inhibited cellulose digestion drastically. Organic forms of sulfer such as those in the forms of cysteine and glutathione were also available but a higher level of sulfur was needed than in the case of sulfate sulfur. Methionine gave a response upon cellulose digestion which was consistently higher than any other forms of sulfur tested, then suggesting that this amino acid supplied something beneficial other than sulfur.

142. A MICROBIOLOGICAL ASSAY FOR THE DETERMINATION OF THE UTILIZATION OF NPN COMPOUNDS BY RUMEN BACTERIA. G. A. McLaren, C. D. Campbell, J. A. Welch, G. C. Anderson and G. S. Smith, *West Virginia University.*

A microbiological assay was developed for evaluating the utilization of various non-protein nitrogen compounds by rumen bacteria. The production of acid at various time intervals after innoculation was used as the criterion for growth. The basal medium consisted of McDougall's solution diluted 1:10 with distilled water, 1% dextrose, 0.05% thioglycolic acid, 0.03% of a vitamin solution containing all B vitamins except B_{12} and choline. Resazurin was used as a redox potential indicator. The NPN source under study was added to provide 0.5% N. One ml. of the supernatant, prepared by centrifuging strained rumen liquor, was added to 9 ml. of the medium in 15 ml. screw cap test tubes. Anaerbiosis was maintained while incubating at 39° C. Enough replicates were prepared so that tubes could be withdrawn and titrated at intervals up to 90 hours. By using this technique it was found that creatine was utilized better than urea and that crude biuret was utilized as well as urea. The system described was also used to determine the effect of B_{12}, diethylstilbestrol (DES), homocystiene (Hc), methionine (Mt.) and guanidinoacetic acid (GA) upon the utilization of various N sources as measured by acid production. The effect of these materials with the different N sources was as follows: B_{12} with urea, creatine, sarosine-negative; DES with biuret, urea-negative; Hc. with sarcosine, urea-negative, with creatine-positive; Mt. with urea-negative with creatine-positive.

143. THE EFFECT OF ROUGHAGE—CONCENTRATE RATIOS UPON PRODUCTION AND RECYCLING OF VOLATILE FATTY ACIDS BY RUMEN MICROORGANISMS. W. H. Brown, E. C. Leffel and S. Lakhsmanan, *University Maryland.*

Sheep were fed on diets containing hay and concentrates in the ratios of 4:1, 3:2, 1:3 and 1:4. Amounts and molar percentages of volatile fatty acids (VFA) in

the rumen fluid were determined and VFA production *in vitro* was studied. Rumen concentrations of total VFA increased as the percentage of concentrates in the diet increased. Molar percent acetate decreased from 60 to 40 and the percent propionate increased from 20 to 40 when the percent concentrate in the diet increased from 20 to 80. Molar proportions of butyrate and higher acids in the rumen fluid were not appreciably affected by changes in the roughage—concentrate ratios. *In vitro* VFA production reflected both the concentrations and molar proportions observed in the rumen fluid as drawn from the animals; the higher rate of production being found in the rumen fluids from animals fed higher proportions of concentrates and the major VFA (acetate, propionate and butyrate) being produced in much the same ratios as found in the rumen. These results suggest that both rumen fluid analyses and short-time *in vitro* studies give a reliable index to VFA production in the rumen. Short time incubations with butyrate $-1-C^{14}$ and acetate $-1-C^{14}$ have shown that in rumen fluid drawn from animals on high concentrate diets, acetate is recycled to butyrate at the rate of 5–6% per hour and butyrate to acetate at a rate of 2–3% per hour; on high roughage diets butyrate is recycled to acetate at the rate of 6–7% per hour.

144. *IN VITRO* RUMEN MICROBIAL PROTEIN AND NUCLEIC ACID ANABOLISM. W. C. Ellis and W. H. Pfander, *University of Missouri.*

The relationship between rumen microbial protein and nucleic acid synthesis was investigated to determine if microbial nucleic acid synthesis could serve as an index to microbial protein synthesis. Donor lambs were fed a low nitrogen basal ration supplemented with either urea, urea plus methionine hydroxy analogue and isoleucine, methionine hydroxy analogue, DL-valine, L-isoleucine, tryptophane and L-lysine, or zein. A method of fractionating rumen ingesta was developed whereby supplemental nitrogen was removed by 74% ethanol; soluble nucleotide and phospholipid phosphorous by 10% cold trichloroacetic acid and ethanol-ether respectively; total nucleic acids by 0.05 N sodium hydroxide; and microbial protein by hot 1 N sodium hydroxide. Rumen ingesta samples were removed and 10 ml. sub-samples placed in anerobic incubation tubes. Individual incubation tubes were removed at intervals, microbial action halted and the ingesta analyzed. It was assumed that initially, within a predetermined experimental error, each tube's contents was homologus; therefore, tubes removed after incubation would contain amounts of microbial protein and nucleic acids equal to that in the zero hour tube plus the amount synthesized for that increment of time. Time-concentration curves were then constructed. A highly significant coefficient of correlation ($r=+0.87$, $P=<0.001$) was found to exist between increases in microbial protein nitrogen (Y, in mgm.) and increases in ribonucleic acid phosphorous (X_2, in mgm.) when time (X_3, in hr.) was held constant. The partial regression equation for this relationship was $Y=0.80+7.23\ X_2+0.11\ X_3$ with a standard error of 0.58 mgm. nitrogen.

145. THE EFFECTS OF VARIOUS LEVELS OF DIETARY PROTEIN AND ENERGY UPON THE VOLATILE FATTY ACIDS IN THE RUMEN OF BEEF COWS. P. A. Putnam and R. E. Davis, *Beef Cattle Research Branch, USDA.*

The rumen liquor of 48 Angus cows, divided into nine lots, was analyzed for acetic, propionic and butyric plus higher acids. Three of the lots (I, II, and III) were full-fed, three (IV, V, and VI) received approximately two-thirds of the full-fed lots, and three lots (VII, VIII, and IX) were fed at a level calculated to maintain weight. Within each energy level one lot received 0.23 lb. digestible protein per cwt. (I, IV, and VII); one received 0.15 lb. digestible protein per cwt. (II, V, and VIII) and one received 0.06 lb. digestible protein per cwt. (III,

VI and IX). All rations were pelleted. Rumen liquor samples were obtained 4 hours after feeding. Average concentrations of all acids were higher ($P<0.05$) in the rumen liquor of cows consuming the high energy (lots I, II and III) and medium protein (lots II, V, and VIII) rations. When the amounts of acids were expressed as a proportion of the total acids no clear trends were evident. The proportion of butyric plus higher acids was greater ($P<0.05$) and the proportion of acetic acid was correspondingly smaller ($P<0.01$) on the high energy rations. On the medium protein rations the proportion of butyric plus higher acids was greater ($P<0.01$) but it was the proportion of propionic acid that was correspondingly less ($P<0.01$). Coefficients of variation ranged from 6.4 to 30.9%.

146. INFLUENCE OF FATTY ACIDS UPON DIGESTIBILITY OF RATIONS BY LAMBS. Kenneth Davison and Walter Woods, *Iowa State College.*

Two series of metabolism trials with lambs were conducted to determine the effect of corn oil (CO) and various fatty acids (FA) on digestibility and nitrogen retention when feeding a 46% corncob ration. In the first series, three groups each of six lambs were fed the following daily rations: 700 gm. basal ration; basal + 36 gm. CO; and basal + 36 gm. FA of a distilled animal type. The addition of CO or FA to the basal ration significantly decreased digestibility of organic matter, cellulose and protein and significantly increased ether extract digestibility; nitrogen retention was decreased. In the second series of trials, four groups each of six lambs received the following rations: 700 gm. basal diet; basal + 8 gm. lauric acid (96%); basal + 36 gm. stearic acid (93%); and basal + 36 gm. oleic acid (86%). The digestibility of organic matter and cellulose were significantly decreased and ether extract was significantly increased in the lambs fed the fatty acids. Trials were conducted to study the effects of lauric, stearic and oleic acids on digestion of cellulose by rumen microorganisms *in vitro*. At the 25 and 50 mg. levels oleic acid did not have as great a depressing effect as lauric and stearic acids. The effect of fatty acids of various carbon-chain lengths and degrees of saturation on cellulose digestion *in vitro* was determined in additional studies.

147. DIGESTIBILITY AND FEEDING VALUE OF SOYBEAN HULLS. Orville G. Bentley, G. V. Quicke and A. L. Moxon, *Ohio Agricultural Experiment Station.*

The increase in production of soybean meal with 50% protein has made soybean hulls available as a mill by-product feed ingredient. The potential use of hulls in ruminant rations has stimulated interest in the digestibility of the nutrients therein. Since they contain 40 to 45% cellulose, the *in vitro* digestibility of cellulose was determined on the hulls and on a number of other milling by-products and on a sample of dehydrated alfalfa meal for comparison. By the *in vitro* technique developed in this laboratory, the cellulose in soybean hulls, soybean flakes and beet pulp was estimated to be 90 to 96% digestible. The other mill feeds all gave values of 50% or less for cellulose digestibility with this *in vitro* technique. Sheep digestion trials gave apparent digestibility coefficients of 54% and 59% for cellulose in soybean hulls and soybean flakes, respectively. During these trials the hulls and flakes were fed as the only feed and the feces voided were very soft, possibly indicating that passage of these materials through the rumen was too rapid for maximum cellulose digestion. Samples of the feces subjected to *in vitro* digestion showed that considerable digestible cellulose remained in them. Three samples of soybean hulls were placed in dacron bags and inserted into the rumen of a fistulated steer. Ninety-six percent of the cellulose in these samples was digested in a 30-hour period. In the sheep digestion trials the apparent digestion coefficient for protein was 84% for the hulls and 86% for the flakes. The materials contained about 10% protein.

148. INFLUENCE OF VITAMIN A ON WOOL GROWTH, WOOL STRENGTH AND REPRODUCTIVE PERFORMANCE IN RAMBOUILLET EWES. Fred R. Campbell, C. W. Livingston, Jr., Maurice Shelton and T. D. Watkins, *Texas Agricultural Experiment Station.*

Fifteen aged Rambouillet ewes were divided into five lots. Two lots (I and V) were fed a low vitamin A basal ration, while three lots (II, III and IV) were fed the basal ration supplemented to supply the ewes with 600, 1200 and 1800 mcg. of vitamin A per head daily. They were placed on a maintenance ration and fed for a period of 310 days. Blood levels of vitamin A just prior to parturition and near the conclusion of the test revealed averages of 13.44 (lot I), 16.59 (lot II), 27.85 (lot III), 33.33 (lot IV) and 17.11 (lot V) mcg. per 100 ml. of blood. Staple length and grease fleece weights did not reveal any variation between lots which could be attributed to differences in vitamin A levels. Stress-strain and alkali solubility tests were conducted on wool fibers from one deficient and one high-level supplement ewe. Stress-strain analyses did not reveal any differences which could be attributed to the different levels of vitamin A. Alkali solubility tests indicated some deterioration had occurred in the wool fibers from the deficient ewe (17.7%). Ewes in lots I and V either failed to drop lambs or dropped dead lambs exhibiting hydrocephalus and/or absence of eyes. Ewes in these lots disclosed symptoms of night blindess, chronic convulsions, weakness and retained placentas. Ewes in lot II (low level vitamin A) dropped weak but live lambs which later died, and disclosed some other symptoms typical of deficiency. All ewes in lots III and IV dropped normal lambs without difficulty.

149. THE ANTI-VITAMIN E EFFECT OF FISH LIVER OIL IN THE PRODUCTION OF WHITE MUSCLE DISEASE IN SHEEP. J. G. Welch, A. L. Pope, W. G. Hoekstra and P. H. Phillips, *University of Wisconsin.*

Experiments were designed to produce white muscle disease in lambs by feeding fish liver oil to ewes. In experiment one, 11 ewes received excellent quality alfalfa hay and the remaining 44 ewes received leached mixed alfalfa hay. Twenty-two of these received 2 oz. of oil as a drench on alternate days plus 2% oil added to the corn (1 lb./ewe/day). Six lambs in the oil treated lot developed white muscle disease. Both leached hay and oil were effective in decreasing plasma vitamin E concentrations in ewes and lambs. Lambs which developed the disease had very low plasma vitamin E concentrations as did their dams. In a second experiment fish liver oil (4%) was added to a 50:50 corn and corn cob mixture. Two lb. of this grain mixture and poor quality leached alfalfa hay were fed to all ewes. Twelve ewes received a supplement of 0.5 gm. of alpha tocopherol per ewe twice weekly. Twenty-four ewes received 0.5 ppm. of selenium and the remaining 24 ewes received no supplement. Prenatal death, white muscle disease, and sudden death were observed in lambs from ewes receiving no additional vitamin E. Combined, these disorders affected 88% of the lambs in the unsupplemented lot and 60% in the selenium lot. All lambs in the lot receiving alpha tocopherol were normal. Selenium appeared to decrease the severity of the disorders. Vitamin E administration increased vitamin E concentrations in ewe and lamb plasma and ewe milk. Oil treatment increased the iodine number of the milk fat and decreased the percent milk fat.

150. EFFECTS OF DIETARY ANIMAL FAT ON FATTY-ACID COMPOSITION OF STEER DEPOT FAT AS DETERMINED BY GAS CHROMATOGRAPHY. R. L. Edwards, S. B. Tove and E. R. Barrick, *North Carolina Agricultural Experiment Station.*

Steers in dry-lot and on pasture were fed concentrates containing animal fat (yellow grease). Eighteen steers in dry-lot were group-fed (six animals per group)

grain rations with 0, 2.5 and 5.0% animal fat for 154 days. Constituent fatty acids in rib-fat samples from each steer were methylated, and gas chromatograms made of the mixture of esters from each sample. Peaks were found for esters of myristic, myristoleic, palmitic, palmitoleic, stearic, oleic, linoleic and linolenic acids, and for four unindentified acids. Percentages of stearic acid in rib fat increased significantly ($P<0.001$) with addition of animal fat to the ration, as did the percentages of total saturated acids ($P<0.05$); these increases were most marked in animals wintered on a low energy regimen prior to the trial. The percentages of linoleic and of one unidentified acid significantly declined ($P<0.05$) as fat was added to the ration. A comparison of rib-fat samples from pasture-fed steers receiving grain with 10% fat or 7–10% salt to limit intake showed that the percentage of myristic acid deposited was significantly increased by feeding fat ($P<0.05$). Diethylstilbestrol implants significantly depressed the deposition of oleic acid ($P<0.01$). A fat-hormone interaction existed in respect to palmitic and palmitoleic acids; the percentage of the latter was very high in all samples.

151. FURTHER STUDIES ON DIETARY FAT AND PROTEIN INTERRELATIONSHIPS. Verle R. Bohman, Marven A. Wade and Clark R. Torell, *University of Nevada.*

Thirty-six weanling Hereford steers averaging 404 lb. body weight were allotted to treatments in a 2 x 3 factoral experiment. The treatments included two levels of animal fat, 0 and ½ lb. daily and three levels of supplemental protein as alfalfa pellets, 0, 3 and 6 lb. daily. The basal ration was native grass hay and a mineral mix of equal parts of bone meal and salt fed *ad lib.* Added dietary fat had no effect on daily gains. Daily gains increased with each level of added protein as follows: native hay alone, 0.81 lb.; with 3 lb. alfalfa, 1.18 lb.; with 6 lb. alfalfa, 1.40 lb. Feed consumption also increased with each added level of protein. Dietary fat increased the level of plasma cholesterol from approximately 100 mg. % initially to 225 mg. % at the end of the winter feeding period with the basal diet. When extra protein was fed with the fat, the plasma cholesterol increased to only 150 to 155 mg. %. The levels of plasma fat paralleled those of plasma cholesterol. Plasma carotene and vitamin A were similar to the levels of plasma fat and cholesterol. The level of blood ketone increased when extra protein was fed. Dietary fat had little influence on this blood constituent. The hematocrit was not affected by any of the dietary treatments.

152. EFFECT OF ADDED STARCH AND FAT IN WINTERING RATIONS FED TO BEEF STEERS. D. D. Hubbard, W. D. Gallup and A. B. Nelson, *Oklahoma Agricultural Experiment Station.*

The effect of added carbohydrate and fat on nitrogen utilization by steers was studied in three balance trials. In the first trial, 440 gm. of corn starch was added to a basal ration of 3,000 gm. prairie hay, 50 gm. minerals (dicalcium phosphate and salt, 1:1), and 600 gm. cottonseed meal; protein content of the ration was reduced from 11 to 10%. In the second trial, 440 gm. of corn oil was added to a basal ration of 3,000 gm. hay, 50 gm. minerals, 585 gm. cottonseed meal, and 323 gm. corn; protein was reduced from 11 to 10%. In the third trial, 400 gm. of corn oil was added to a high-protein ration of 3,000 gm. hay, 50 gm. minerals, 350 gm. Drackett, and 454 gm. cottonseed meal; protein was reduced from 17 to 15%. Corn starch increased nitrogen retention significantly ($P<.01$) but reduced digestibility (apparent) of protein and crude fiber ($P<.01$). Corn oil added to the corn-cottonseed meal ration and to the high-protein ration of lower energy content had no effect on nitrogen retention but decreased digestibility ($P<.01$ of total dry matter and crude fiber. Corn oil increased fecal ash but did not alter calcium retention significantly.

153. EFFECT OF LEVEL OF WINTERING UPON THE GROWTH AND REPRODUCTIVE PERFORMANCE OF BEEF HEIFERS. J. E. Zimmerman, L. S. Pope and D. F. Stephens, *Oklahoma Agricultural Experiment Station.*

Three trials were conducted with grade Hereford heifers (42–45 per trial) to study the effect of three levels of wintering on growth and early reproductive performance. All heifers grazed native grass year-long. Supplemental winter feed (cottonseed meal and milo) was varied in an attempt to obtain the following weight gains from early November to mid-April: First winter as calves; Low level, no gain; Medium, 0.5 lb. gain per day; High, 1.0 lb. gain per day. Second and subsequent winters; Low, 200 lb. loss; Medium, 100 lb. loss; High, no loss in weight. All heifers were bred to calve in February and March as two-year-olds. Calves were weaned in early October. Data are available on three calf crops in the first trial, two in the second, and one in the third. No consistent differences were observed in difficulty at first calving or percent calf crop weaned. Birth weights were significantly reduced in the low level lots in all trials in two years, but differences were not significant in the third year. Low level heifers calved an average of eight days later than medium level heifers, and 14 days later than high level heifers. Higher levels of winter supplement resulted in heavier calves at weaning, but the increased weaning weights did not offset the increased cost of winter supplement. Body measurements at six-month intervals indicate that level of wintering significantly affected heart girth, depth of body and width, but not height at withers. Additional data have been obtained including performance to weaning of the 1958 calf crop.

154. COMPLETE HIGH-ENERGY ENSILED RATIONS FOR FATTENING BEEF CALVES. A. L. Neumann, G. L. Heuberger, John Buric, G. E. Mitchell, Jr., and W. W. Albert, *University of Illinois.*

Hereford steer calves were fed the following rations for 224 days: A, ground shelled corn, corn silage, and soybean oil meal; B, complete-ration silage which contained 60% alfalfa forage and 40% ground shelled corn (12.75% protein); C, complete-ration silage consisting of 60% whole oat plants and 40% ground shelled corn with 5 lb. of urea per ton (12.44% protein); and C, complete-ration corn silage with 10 lb. of urea per ton and enough ground shelled corn added to give a corn content equal to B and C (11.88% protein). All steers received 2 lb. of alfalfa hay daily. Ten steers received the control ration A, and three groups each of 20 steers were fed rations B, C, and D for 140 days (Phase I). During the last 84 days (Phase II) the steers receiving rations B, C, and D were divided so that one-half of each group received an additional pound per head of ground shelled corn daily and the other half received an equal amount of soybean oil meal. Rations, average initial weights, final weights, average daily feed intakes on a 90% dry matter basis (ADF), ADF per cwt. gain, and daily gains were respectively: Phase I-A, 417, 773, 16.8, 661.1, and 2.54; B, 419, 745, 15.3, 659.2, and 2.33; C, 421, 704, 14.2, 703.7, and 2.02; and D, 422, 723, 15.8, 728.1, and 2.15. Phase II-A, 733, 949, 19.4, 923.9, and 2.09; B, 745, 926, 19.6, 907.0, and 2.15; C, 699, 839, 15.8, 946.3, and 1.66; D, 728, 882, 17.4, 943.8, and 1.83. For 224 days, A, 417, 949, 17.8, 748.0, and 2.37; B, 419, 926, 16.9, 747.5, and 2.26; C, 421, 839, 14.8, 783.8, and 1.89; and D, 422, 882, 16.4, 796.2 and 2.04. Soybean meal produced significantly faster gains than corn when added to D but not when added to B or C.

155. EFFECT OF VARYING THE CONCENTRATE-TO-ROUGHAGE RATIO IN SELF-FED MIXTURES FOR FATTENING STEERS AND HEIFERS. J. E. McCroskey, L. S. Pope, L. E. Walters and D. E. Stephens, *Oklahoma Agricultural Experiment Station.*

In three trials involving 236 long-aged steer and heifer calves, the effects of widely varying concentrate:roughage ratios on feedlot performance and carcass grade were investigated. In two trials, concentrate:roughage ratios of 35:65, 50:50, 65:35 and 80:20

were tested; in a third trial the 35:65 ratio was omitted. Ground milo, cottonseed meal and molasses were the concentrates fed; the roughage was a mixture of equal parts of chopped alfalfa hay and cottonseed hulls. Digestible protein, calcium and phosphorus were equalized in all rations. Within each trial, treatments were replicated. A comparison was made between steers and heifers on each ration. The cattle were removed from test individually at a grade of high-good to low-choice. No significant difference in average daily gains of steers was observed. Heifers consistently made most rapid gains on the 50:50 ratio, although the difference was significant ($P<.05$) in only one trial. Carcass grade and TDN required per cwt. gain were not consistently different between treatments. Time on feed was least for calves fed the 50:50 ratio, and greatest for those fed the 35:65 ratio. Daily feed intake declined as percentage of concentrate in the ration increased, thus tending to equalize TDN intake. Steers made significantly faster gains than heifers ($P<.05$) and were more efficient in feed conversion. Heifers graded higher in the carcass. Results indicate that self-fed mixtures for calves may vary widely in concentrate:roughage ratios with little apparent effect on feedlot performance or carcass merit.

156. TECHNIQUES FOR THE DETERMINATION OF ENERGY METABOLISM AND GRAZING BEHAVIOR WITH SHEEP. Eric Cresswell and Lorin E. Harris, *Utah State University.*

The technique of using a modified field pattern tracheal cannula has been established at this laboratory for calorimetry work with sheep in the field. The technique is based on the need to isolate pulmonary exchange from rumen gases which are particularly voluminous when the ruminant is on full feed. The particular snags of the use of the face mask are of course the inability of the operator to prevent the entry of methane into an oxygen spirometer, and, obviously, of the animal to feed. The technique here used involves the use of tracheal block introduced at will above a fistula in the trachea. This means that to the operators order all communication between the trachea and the pharynx is severed and therefore a true picture of the oxygen consumption of the animal can be obtained with great facility. The application of this technique in the field requires the careful conditioning of experimental animals to handling in order that they may be approached and worked with without any physicological disturbances. Field apparatus has been developed to determine the oxygen consumption of grazing animals. An improved range meter consisting of a wheel, a measuring device and a harness attached to a sheep has been worked out to measure the distance a sheep travels while grazing.

157. MILK PRODUCTION, FEED INTAKE AND DIGESTIBILITY FOLLOWING INITIATION OF LEGUME-GRASS SILAGE FEEDING. H. R. Conrad, J. W. Hibbs, A. D. Pratt and J. H. Vandersall, *Ohio Agricultural Experiment Station.*

Five autumn and winter feeding experiments involving 68 cows showed that milk production dropped 10 to 22% when the cows were shifted abruptly from mixed hay and corn silage to legume-grass silage, even when hay made up 50% of the roughage dry matter. Seventy-three digestion and nitrogen balance trials were carried out to determine some of the principal causes of the observed decline in milk production. Abrupt changes to all grass silage resulted in suppressed dry matter intake and digestibility for a 2- to 3-week period which coincided with depressed milk production. In another experiment, to minimize the effect of roughage changes on digestion, approximately one-half of the roughage was supplied by mixed hay. In contrast, in the latter experiment, the daily dry matter digested was uniform for 5 weeks after the change in kind of silage fed; 15.6 lb. were digested when corn silage and hay were fed and 16.8 lb. when grass silage and hay were fed. Daily nitrogen retention was 16.9 gm. and 29.0 gm. respectively, for the corn silage and legume-grass silage feeding periods. Despite the higher digestible nutrient intake when grass legume silage was fed, milk production declined 10% in a six-day period. These results suggest that legume-

grass silages contain substances which inhibit milk production independent of the effects of digestibility.

158. INFLUENCE OF WHEAT STRAW, CORN COBS, OAT MILL FEED AND BAGASSE PITH UPON DIGESTIBILITY AND NITROGEN UTILIZATION BY LAMBS. G. S. Smith, G. C. Anderson, J. A. Welch, G. A. McLaren and C. D. Campbell, *West Virginia University*.

Sixteen grade wether lambs were fed semi-purified rations composed of a purified concentrate mixture, blackstrap molasses, and one of four roughages. The rations were approximately isocaloric and isonitrogenous. Two-thirds of the total ration nitrogen was supplied by urea. The corn cob ration gave significantly ($P<0.01$) higher digestibility of organic matter, crude fiber, nitrogen-free extract, pentosans, cellulose, and energy than was obtained with any of the other rations. The nitrogen-free extract of the oat mill feed ration was significantly ($P<0.01$) better digested than that of the wheat straw ration; however, the digestibility of pentosans of the wheat straw ration was greater ($P<0.01$) than in either the oat mill feed or bagasse pith rations. The digestibility of crude protein in both the corn cob and oat mill feed rations was higher ($P<0.01$) than in the ration containing bagasse pith. The percent retention of absorbed nitrogen was higher ($P<0.01$) with the corn cob ration than with the bagasse pith ration. The digestibility of cellulose in all four roughages was greater ($P<0.05$) by approximately 9% than was the digestibility of pentosans.

159. THE EFFECT OF DIFFERENT COMBINATIONS OF ENERGY AND PROTEIN ON RATION DIGESTIBILITY BY BEEF HEIFERS. C. J. Elam, R. E. Davis, J. N. Wiltbank, and E. J. Warwick, *Beef Cattle Research Branch, USDA*.

Fifty-four Angus heifers were divided into nine equal lots. Three lots (I, II and III) were full fed, three (IV, V and VI) received two-thirds of full fed lots, and three (VII, VIII and IX) were fed a maintenance level. Within each energy level one lot received 0.23 lb. digestible protein per cwt. (I, IV and VII); one received 0.15 lb. digestible protein per cwt. (II, V and VIII) and one 0.06 lb. digestible protein per cwt. (III, VI and IX). The rations were pelleted and heifers in lots IV through IX were fed individually. One heifer in lot VII died after about 11 months. After one year on these rations, chromic oxide was mixed into each ration at 0.5%. Following a 10-day preliminary period, grab samples of feces were collected from each heifer at 9 a.m. and 3 p.m. for 5 days. Equal weight samples were pooled to form a composite sample for each heifer. The average digestibility of organic matter (OM), NFE, and energy was significantly greater ($P<0.01$) for the medium energy heifers (IV through VI) than either the high or low energy lots. Average digestibility of crude protein (CP), ether extract (EE), and crude fiber (CF) was significantly lower ($P<0.01$) in the high energy lots (I through III) than the medium or low energy lots. Low protein lots (III, VI and IX) digested significantly less ($P<0.01$) OM, EE, CF, and energy than medium or high protein lots. Average apparent crude protein digestibility was directly related to level of protein fed and NFE digestibility was not affected by level of protein intake.

160. LEVELS AND RATIOS OF VOLATILE FATTY ACIDS AS ROUGHAGE SUBSTITUTES FOR GROWING-FATTENING LAMBS. H. W. Essig, E. E. Hatfield and B. Connor Johnson, *University of Illinois*.

Thirty-six individually fed lambs were used in three experiments to study the effect of using volatile fatty acids (VFA's) as an energy source, a substitute for roughage, and to study optimum ratios and levels. Weight gains and carcass grades were used as criteria of evaluation. A basic synthetic diet containing Drackett protein, sucrose, granulated starch, corn oil, vitamins and minerals was used in all experiments.

In experiment I, 12 animals were assigned at random to four treatments as follows: Treatment 1, 31.9% dehydrated cobs; treatment 2, 31.9% salts of VFA's (23% VFA's); treatment 3, 31.9% added granulated starch; treatment 4, no roughage or energy substitute. The ADG was as follows: treatment 1, 0.17 lb.; treatment 2, 0.31 lb.; treatment 3, —0.26 lb.; treatment 4, —0.05 lb. In experiment II, 12 animals were assigned at random to four treatments to study effects of different ratios of VFA's, part as liquids and part as salts. The treatments containing liquid VFA's resulted in reduced consumption and poor gains. In experiment III, 12 animals were assigned at random to four treatments to study effects of different ratios of VFA's using sodium, calcium and magnesium salts. A total of 24% VFA's were used in each treatment, with variation of 15–3% acetic acid, 6–12% propionic acid and 3–9% butyric acid. There were no differences in ADG (0.33 to 0.39 lb.) for the four ratios used. These results substantiate that salts of VFA's can be used as a roughage substitute. These data indicate that a specific ratio of VFA's is not critical for producing satisfactory lamb gains. These investigations are being continued using graded levels of total VFA's ranging from 24–42%.

161. USE OF THE CHROMIC OXIDE METHOD FOR DETERMINING DIGESTIBLE ENERGY AND PROTEIN IN COMPLETE PELLETED STEER RATIONS. N. W. Bradley, R. M. Forbes, W. W. Albert, G. E. Mitchell, Jr., and A. L. Neumann, *University of Illinois.*

Chromic oxide excretion patterns of six steers were compared when indicator was administered by capsule or orally as a part of a complete pelleted ration fed at 8 a.m. daily during twelve, 24-hour collection periods for each method, with fecal collections being made at 2-hour intervals. The chromic oxide concentration in the individual fecal samples, expressed as a percent of the mean 24-hour concentration, varied from 57 to 208% when administered by capsule but only from 73 to 155% when administered in the pelleted ration. The general shape of the two excretion patterns was similar. Optimum sampling plans were to use composited samples taken at 6 and 10 a.m. for capsule administration and 8 and 10 a.m. when chromic oxide was mixed in the feed. Eight steers, fed the complete pelleted ration with indicator at 8 a.m. daily, were used in a 7-day collection period to compare the total collection method with the 8 and 10 a.m. composited grab sampling method. Apparent digestion coefficients for energy were 71.96 $\pm$ 3.40 and 72.6 $\pm$ 3.17 and for protein, 71.60 $\pm$3.18 and 71.88 $\pm$ 3.19, respectively, for the two methods. The reduction in variability in chromic oxide excretion in the pelleted ration method of administration and the similarity in the apparent digestion coefficients determined by total collection and by 8 and 10 a.m. composited grab samples would suggest a simple method for determining the digestibility of total dry matter or of individual nutrients in beef cattle rations under practical feed-lot conditions.

162. THE FECAL EXCRETION PATTERN OF CHROMIC OXIDE WHEN ADMINISTERED TO HEREFORD HEIFERS IN A COMPLETELY PELLETED RATION. C. J. Elam, P. A. Putnam, and R. E. Davis, *Beef Cattle Research Branch USDA.*

Chromic oxide (Cr_2O_3) was mixed uniformly into a pelleted ration at 0.5% and fed to three Hereford heifers per treatment. Treatments were: (1) limited-fed once daily (LOD), (2) full-fed once daily (OD), (3) full-fed twice a day (TD), and (4) *ad libitum* (AL). After a nine-day preliminary period, fecal samples were collected at three-hour intervals for 48 hours. Dry matter and Cr_2O_3 analyses indicated that a significant ($P<0.05$) time-concentration variation occurred in fecal Cr_2O_3. Furthermore, Cr_2O_3 excretion was influenced by the different feeding schedules. Respective peak concentrations of Cr_2O_3, expressed as percent of daily mean, and times at which the

peaks occurred were as follows: (1) LOD, 112% at 9 p.m., (2) OD, 108% at 12 a.m., (3) TD, 111% at 3 p.m., and (4) AL, 109% at 9 a.m. The magnitude of the variation in fecal Cr_2O_3 concentration, exhibited during a 24-hour period, precludes the indiscriminate sampling of feces for digestion trials as regards time. However, it is thought that the individual variation exhibited by different animals fed Cr_2O_3 in pellets is less than when administered in gelatin capsules. The extremes found in individual observations in this experiment were low 74% and high 135%. Four beef steers were fed (TD) a predominantly roughage ration which was ground, mixed with Cr_2O_3 and pelleted. Analyses of feces samples collected in the morning and afternoon for 8 days resulted in Cr_2O_3 concentrations which tended to support the type of excretion pattern found in the twice a day feeding.

163. CHROMIC OXIDE IN A SUSTAINED-RELEASE PELLET TO REDUCE VARIATION IN ITS DIURNAL EXCRETION PATTERN IN CATTLE. G. J. Brisson and W. J. Pigden, *Dept. of Agriculture, Ottawa, Canada.*

Chromic oxide (Cr_2O_3) was given in pellet form (½ Cr_2O_3+½ Kerr's plaster+water) once per day at 4 p.m. to two steers (E–1) and two cows (E–2). Fresh grass was fed at 7 a.m. and 4 p.m. Rectal samples were taken at regular intervals for 5 and 7 consecutive days in E–1 and E–2, respectively. The Cr_2O_3 concentration expressed as per cent of the respective daily mean concentraction was 100.3±2.5 at 7 a.m., 95.3±2.4 at 10 a.m., 96.5±2.6 at 1 p.m., 100.5±2.5 at 4 p.m., 100.8±1.7 at 7 p.m., 102.4±1.9 at 10 p.m., 100.2±1.73 at 1 a.m., and 99.0±1.53 at 4 a.m. The small differences between these concentrations were not statistically significant by analysis of variance. Total recovery measured only in E–1 was 100.4% for a period of 14 days preceding the rectal sampling period. There was no regurgitation of the pellets in either E–1 or E–2.

164. USE OF POULTRY SLAUGHTER BY-PRODUCTS IN STEER FATTENING RATIONS. Maurice L. Ray and W. T. Wallace, *University of Arkansas.*

By-products of the poultry processing industry, being high in nitrogen and low in fiber apparently afford a source of protein that might be used in beef fattening rations. Sixteen Hereford steers, with an average initial weight of 642 lb., were individually fed in four groups for 104 days. All steers were fed lespedeza hay and a grain ration consisting of 9 parts ground yellow corn and 1 part protein supplement. Supplements were hydrolyzed feather meal, poultry blood and bone meal, cottonseed meal, and a 1-1-2 mixture of the above for groups 1, 2, 3 and 4, respectively. Average daily gains were 1.96, 2.20, 1.99 and 2.15 lb. while feed per pound of gain was 7.64, 7.46, 8.53 and 7.65 lb. for groups 1, 2, 3 and 4, respectively. Representative animals were selected after the feeding trial for digestion and slaughter studies. Digestion coefficients indicated that animals receiving rations containing poultry slaughter by-products digested their rations as well or better than those receiving cottonseed meal. Carcasses from all animals were acceptable with grades being low good to low choice. Lowest carcass grades were from steers fed feather meal while highest were from those fed poultry blood and bone meal. In this study, steers utilized poultry slaughter by-products satisfactorily when measured in terms of gain, digestibility, feed efficiency and carcass grade.

165. AN UNIDENTIFIED GROWTH FACTOR SOURCE IN RATIONS OF BROOD SOWS. H. G. Luther, N. D. Magruder, W. M. Reynolds and W. C. Sherman, *Chas. Pfizer & Co., Inc., Terre Haute, Indiana.*

Two groups of 49 hybrid sows and gilts were used in this trial. All received a full-ration gestation-lactation diet which did not contain fish meal. Half received, in addition, from 3 days pre-farrowing to 7 days post-farrowing, 0.45% of a concentrated

fermentation source of unidentified factors (Vigofac, Chas. Pfizer & Co., Inc.). In the first seven days, average baby pig gains were 2.55 lb. and 2.78 lb. for the offspring of control and treated females, respectively. Corresponding average litter weights at the end of 7 days were 55.6 lb. and 59.6 lb. Differenences between groups were found significant by statistical analysis. There were no significant differences between groups in numbers of pigs farrowed per litter, average birth weights, numbers of pigs born dead and numbers weaned. The trial was discontinued at 7 days because of an early weaning program.

166. EFFECT OF ORGANIC PHOSPHORUS BOLUSES ON GRUB COUNT AND FEED LOT PERFORMANCE OF BEEF STEERS. W. W. Albert, B. G. Smith, G. E. Mitchell, Jr., and A. L. Neumann, *University of Illinois.*

Two trials have been conducted to determine the effects of administering organic phosphorus boluses (Trolene) to feeder calves. Sixty-nine Texas feeder calves which averaged 420 lb. were used in the first trial. Thirty-five calves were treated with Trolene on November 26. The other 34 calves were not treated. Five calves from each group were fed corn silage, alfalfa hay, and ground shelled corn. The remaining calves were fed high-energy, complete ration silages. Average grub counts for control steers were 31.7 on November 26, 18.4 on December 24, and 4.9 on January 21. Average grub counts for treated steers were 31.6, 9.8, and 0.4 on the same dates. Average initial weights, final weights, total gains, and daily gains respectively were 418, 793, 375, and 2.23 lb. for control steers and 422, 797, 375, and 2.23 lb. for treated steers. In a second trial half of the steers in a group of 48 Colorado feeder calves were treated with Trolene on December 10. Grubs were not detected in either the control or the treated steers. Average daily gains for 140 days were 1.84 and 1.83 lb. for control and treated steers, respectively. No harmful side-effects of Trolene administration were observed in either trial.

167. EFFECTS OF THE REPLACEMENT OF DIETARY CALCIUM BY STRONTIUM ON PIGS THREE TO EIGHT WEEKS OF AGE. John C. Bartley, Elwood F. Reber and Dragutin Maksic, *University of Illinois.*

Two litters of Hampshire pigs were obtained at 28 days of age. Four pigs were fed a synthetic ration containing 500 mg. of calcium per 100 gm. of ration, as fed. Five pigs were fed the same ration in which the calcium was replaced with strontium. The rations were fed for 35 days. At 21 days the pigs fed the ration containing strontium appeared to have muscular weakness and lack of coordination in the rear quarters, bowed legs, enlarged epiphyseal cartilage. They had a peculiar squeal though they did not appear to be hypersensitive. They choked and salivated excessively when offered feed and water. The average daily gain of the pigs fed the rations containing calcium and strontium was 0.48 and 0.36 lb., respectively. There were no differences in the total red blood cell, white blood cell and differential leucocyte counts due to feeding calcium or strontium. Paper electrophoretic analysis of serums revealed 44.3% and 34.2% albumin for the pigs fed rations containing calcium and strontium, respectively. At necropsy hematomas were observed in the tissue adjacent to the lateral distal condyle of the femur. There did not appear to be any difference in the length of the femurs. There was a decrease in the percntage of fat and ash and increase in total solids of femurs of pigs fed strontium as compared to those fed calcium. One hind and one fore-limb of each pig was x-rayed. Bones of pigs fed strontium revealed a lack of density at the joint surfaces.

168. THE DIGESTION OF CORN AND SORGHUM SILAGE BY LACTATING AND GROWING DAIRY CATTLE. J. H. Byers, *University of Illinois.*

In trial 1, two groups of five lactating cows each were fed 1 lb. of good alfalfa hay per 100 lb. of bodyweight and 1 lb. of concentrate per 4 lb. of milk produced

in addition to either corn or sorghum silage *ad libitum*. The corn silage was well-eared but cut too late while the hybrid grain sorghum was cut in the dough stage. Mean digestion coefficients determined by the chromic oxide technique were, organic matter, 71.6, 62.8; crude protein, 71.1, 60.9; ether extract 62.9, 41.4; crude fiber, 58.7 45.4; and NFE 77.8, 70.9% for the corn silage and sorghum silage rations, respectively. Only the differences in digestibility of the organic matter were statistically significant with the sorghum silage superior to the corn silage. In trial 2, 14 heifers divided equally into two groups were fed the same corn and sorghum silages *ad libitum* and 2 lb. per animal per day of an 18% crude protein grain mix. By the chromic oxide technique, mean digestion coefficients were, organic matter, 61.6, 58.8; crude protein, 51.6, 58.5; ether extract, 68.5, 77.5; crude fiber, 49.8, 51.3 and NFE, 71.4, 67.7 for the corn and sorghum silage rations respectively. In trial 3, the same 14 heifers were fed only the silages. The coefficients of digestibility were lower than when the heifers received the grain. The sorghum silage was still superior to the corn silage but not significantly. In these trials sorghum silage cut in the dough stage was superior to too mature well-eared corn silage. The addition of 2 lb. of grain to a silage ration for heifers improved the digestibility of the ration but not significantly.

169. EFFECT OF STILBESTROL ON PROTEIN REQUIREMENTS OF FATTENING STEERS. Edwin E. Goodwin, *Louisiana State University Rice Experiment Station.*

Three levels of protein were tested with and without 24 mg. stilbestrol implants (SI) for fattening 2-year-old steers with crushed ear corn and brewers' rice on summer pasture. These levels of protein approximated the low, middle, and high range of Morrison's recommended nutrient allowances. On the low leved (L), no protein supplement was fed; on the middle (M) and high (H) levels, 0.5 lb. and 1.0 lb. of soybean cil meal per head daily were fed, respectively. Each group of 12 steers was fed the same equivalent daily concentrate allowance per head, which amounted to essentially a full feed at an average of approximately 10 lb. per head daily during the 92-day feeding period. Forage of Dallis grass, common Bermuda grass, and some lespedeza was in surplus availability throughout the summer in all pastures. In this experiment, the low level of protein appeared to be adequate only for implanted steers. Stilbestrol implants increased gains on all protein levels. The average daily gains were: L, 1.34 lb.; LSI, 2.16 lb.; M, 1.79 lb.; MSI, 2.13 lb.; H, 1.84 lb.; and HSI, 2.00 lb. Stilbestrol had no apparent effect on shipping shrinkage, dressing percentage, and carcass grade. This experiment is being repeated.

170. REMOVAL OF "FRINGED TAPEWORM" FROM FEED-LOT LAMBS WITH HYGROMYCIN. George W. Kelley, M. A. Alexander, and Lionel Harris, *University of Nebraska.*

Wyoming feeder lambs were divided into six lots each of 50 lambs. Three lots received 24,000 units hygromycin B per lamb daily for about 3 months. The remaining lots remained untreated. Livers were examined for fringed tapeworm at slaughter. Only 8.8% of the treated lambs had tapeworm-infected livers whereas 45.7% of the livers of the untreated lambs were wormy. In general, the treated lambs reached market weight earlier and had better feed efficiency than the untreated lambs. However, the cost of the medicament offset this difference, making the cost per pound almost equal for the two groups.

171. EFFECT OF INTAKE ON THE INCIDENCE OF BLOAT AND CERTAIN PROPERTIES OF RUMEN CONTENTS. W. E. Thomas, *North Carolina State College.*

Ten grade beef steers weighing approximately 700 lb. were grazed bloating Ladino Clover for either 15 minutes or 1½ hours twice daily in a single reversed type trial.

Stomach tube samples were collected 1½ hours after grazing was started in the morning and specific gravity, pH and ingesta volume increase determined. The steers were rated for bloat by observation and were measured around the most distended portions. None of the steers bloated from the short grazing periods. Three of the five bloated when left on the forage 1½ hours in the final phase and two of the other five bloated when reversed from 15 minutes to 1½ hour grazings. The following values were obtained for 15 minutes and 1½ hour grazings respectively: Girth change —0.65 in. +5.8.; rumen pH 6.97, 6.28; specific gravity 0.97, 0.59 and ingesta volume per 100 gm. with incubation 148, 318. Each of the values represent 20 observations. Two of the steers were sampled through permanent fistula in addition to the stomach tube samples.

172. EFFECT OF GRASS-LEGUME SILAGE ON THYROID ACTIVITY. J. H. Vandersall, J. W. Hibbs and H. R. Conrad, *Ohio Agricultural Experiment Station.*

A reduction of 10–22% in milk production has been observed when cows are changed abruptly to rations containing legume-grass silage. As reported in a companion paper, this reduced milk flow can not always be attributed to a lower intake of digestible nutrients. This indicates that some substance(s) in legume-grass silage was responsible for the lowered milk production. Preliminary studies suggested that thyroid activity may be involved. I-131 uptake of heifers was determined previous to, and one week after being changed to legume-grass silage as their sole roughage. When the silage was predominantly legume, two heifers fed silage exhibited a lowered I-131 uptake as compared to their previous uptake and a control fed on legume-grass hay. When the silage was predominantly grasses, two other heifers showed no apparent effect of the silage on I-131 uptake. The lowered I-131 uptake in the heifers fed silage high in legumes suggests that lowered thyroid activity may be responsible for the observed decline in milk production. It is postulated that goitrogenic substance(s) may be formed in the legume-grass silage during the fermentation processes. This might account for the lowered I-131 thyroid uptake and the drop in milk production. This concept is being further checked by reversal and paired experiments currently being carried out on 16 heifers.

173. A COMPARISON OF LOW VERSUS HIGH MOISTURE SHELLED CORN FOR GROWING-FINISHING SWINE. J. H. Conrad and W. M. Beeson, *Purdue University.*

Three experiments with a total of 140 Duroc weanling pigs have been conducted to compare the relative feeding value of low moisture shelled corn (11.5 to 18.5% moisture) and ensiled high moisture shelled corn (26 to 32% moisture) for growing-finishing swine. Shelled corn in a particular experiment was harvested from the same field. High moisture shelled corn was picked when the corn contained approximately 30% moisture, shelled, then stored in an air-tight glass-lined silo. Four to six weeks later, the low moisture corn was picked and stored either as ear corn or shelled corn. Pigs in all three experiments were fed free-choice shelled corn and protein supplement. In experiment I, pigs fed high-moisture corn (31.8% moisture) gained 3% faster, consumed 11% more corn and 10% more supplement but required 8% more corn and 7% more supplement per 100 lb. of gain compared to pigs fed low moisture corn (18.5% moisture). In experiment 2, pigs fed high moisture corn (32.4% moisture) gained 5% faster but required 8% more corn and 21% less supplement per 100 lb. of gain compared to pigs fed low moisture corn (11.5% moisture). After 70 days, pigs in experiment 3 fed high moisture shelled corn (25.6% moisture) were gaining at the same rate but were requiring 14.2% more corn and 3.3% less supplement than pigs fed low moisture corn (14% moisture). All comparisons with regard to corn are on a moisture equivalent basis.

174. MANGANESE REQUIREMENTS OF GROWING AND FATTENING CATTLE. L. B. Embry, G. F. Gastler, D. V. Radabaugh and O. E. Olson, *South Dakota State College.*

Three sets of steer and four sets of heifer twin calves which appeared identical were fed a low-manganese basal ration composed of ground ear corn, 61%; ground corn cobs, 20%; dried blood meal, 4%; dried brewers yeast, 3%; dried buttermilk, 3%; beet sugar, 5%; urea, 0.5%; limestone, 2%; bone meal, 0.5%; and salt with iron, iodine, cobalt, copper, and zinc, 1%. Vitamin A and vitamin D concentrates were added to the ration. A composite of several samples of the mixture taken during the experiment analyzed about 15 ppm of manganese. The calves were obtained at a young age and fed alfalfa hay and oats. As each pair reached about 400 lb., they were fed the basal ration for a 16-week depletion period. Then one of each pair remained on the basal ration and the other received the basal ration with 30 ppm of added manganese. The length of feeding after the depletion period varied from 196 to 415 days for various pairs. Average daily gain, average daily feed consumed, and feed per 100 lb. gain in pounds during the test period for the basal and manganese-supplemented groups, respectively, were 1.37, 1.42; 15.8, 15.9; and 1156, 1146. Each pair appeared very similar when taken off the experiment and had obtained a high degree of finish in most cases. There appeared to be no response from supplementing the basal ration (15 ppm manganese) with additional manganese.

175. SOME EFFECTS OF VARIATION IN DRYING TEMPERATURE, HEATING TIME, AIR FLOW RATE, AND MOISTURE CONTENT ON NUTRITIVE VALUE OF FIELD SHELLED CORN. C. A. Cabell, R. E. Davis, and R. A. Saul, *Agriculture Research Service, USDA.*

New machine methods for harvesting and drying have imposed variables with unknown effects on nutritive and marketing value of corn. To test effects of some of these variables, samples were prepared by both heated and unheated air methods of grain drying. A wide range of temperature and controlled air flow rates were employed. Complete temperature histories of different layers of the samples are available in the form of charts. Protein nutritive value measured by two rat feeding methods, growth and repletion, was relied on for estimating nutritive losses. Drying 25% moisture corn with air heated to approximately 198° F. for 4 hours with an air flow rate of 80.5 cfm/bu. did not reduce protein nutritive value significantly. Corn with initial moisture of 29 to 32% dried for 1½ hours or less (with air of approximately 240° F.) and air flow rates of 110 to 112 cfm/bu. was undamaged in drying. Temperatures above this (280° F., at the same air flow rates) caused marked brown discoloration, parched corn odor, and losses in protein nutritive value shown by both rat assay methods. Drying 28% moisture corn with unheated air at an air flow rate of 0.85 cfm/bu. resulted in mold development, high fat acidity values, and indications of losses in protein nutritive value. Increased air flow or reduced original moisture prevented marked mold development and loss of protein nutritive value in corn dried with unheaed air. A limited number of carotene determinations indicated that the drying treatments caused no significant losses of carotene in the corn samples.

176. EFFECT OF PROTEIN-ENERGY RATIO WITH AND WITHOUT THE ADDITION OF STILBESTROL AND OXYTETRACYCLINE ON METABOLIZABLE ENERGY AND PROTEIN DIGESTIBILITY, AND PERFORMANCE IN STEERS. I. A. Dyer and W. E. Ham, *State College of Washington.*

Forty-eight yearling steers were allotted to 16 groups in a 2^2 factorial design. Variables in treatment were protein level, energy level, and oxytetracycline and/or stilbestrol. The difference in the energy level was made by the addition of animal fat (tallow) to the ration. Stilbestrol was administered as implants (14 mg.). Oxytetra-

cycline was fed as TM–10, 1 lb. per 100-lb. animal weight. Duration of the experiment was 63 days, and the animals were individually weighed three times during the trial period. The steers were individually fed and feed-consumption was determined for each animal. At the end of the trial, collections were made for digestibility studies. Interrelationships between oxytetracycline, stilbestrol, and the protein-energy ratio of the ration can be shown in rate of gain and feed efficiency. There likewise appear to be treatment effects upon the digestibility of protein and energy.

177. METABOLIC FECAL NITROGEN IN LAMBS AS DETERMINED BY REGRESSION AND BY LOW NITROGEN RATIONS. J. A. Welch, G. A. McLaren, G. C. Anderson, G. S. Smith and C. D. Campbell, *West Virginia University*.

An attempt was made to utilize regression analysis for the determination of the metabolic fecal nitrogen (MFN) of lambs fed each of four roughages (wheat straw, corn cobs, oat mill feed and bagasse pith) in semi-purified rations. Each roughage was fed to three or four lambs at four levels of ration protein (N x 6.25), which averaged 11.1, 7.5, 5.3, and 2.2%. Reduction in the percentage of ration protein was accomplished by withdrawing increasing amounts of purified soybean protein and urea from the rations and replacing them with dextrose and starch. In contrast with published observations involving natural rations, the gm. of fecal N per 100 gm. of dry matter intake did not decrease with decreases in percent ration protein. MFN was estimated also by feeding semi-purified rations containing each of the four roughages mentioned above without supplemental nitrogen. Undigested roughage was recovered by washing the fresh feces over a 100-mesh screen. The amount of nitrogen in the undigested roughage was then determined. After correcting fecal nitrogen for this undigested nitrogen, the values obtained for MFN were not significantly different among the four roughage rations. The mean MFN was 0.435 ± 0.016 gm. N per 100 gm. dry matter intake.

178. COMPARISON OF SEVERAL LABORATORY METHODS AS USED IN ESTIMATING THE NUTRITIVE VALUE OF FORAGES. B. R. Baumgardt, J. L. Cason and R. A. Markley, *Rutgers, The State University of New Jersey*.

The efficacy of several *in vitro* techniques for potential use in estimating the nutritive value of forages was studied with 11 forages (three alfalfa and eight grasses) of known digestibility as determined in conventional digestibility trials. Included in the laboratory methods were two that have been proposed specifically for such evaluation studies: (1) Digestible Laboratory Nutrients, DLN (Agron. J., 47:302. 1955) and (2) the prediction of TDN from anthrone carbohydrate digested *in vitro* (J. Animal Sci., 14:1239. 1955). Also used as laboratory measures were cellulose and dry matter digestion as determined *in vitro* by the artificial rumen technique. Values taken from the digestion trial data and used as reference guides included (1) TDN, (2) digestible calories per gram as well as digestion coefficients for (3) organic matter, (4) dry matter, (5) fiber, (6) cellulose, and (7) energy. Of the laboratory methods used, cellulose digestion appeared to be the most closely related to the *in vivo* digestibility data. The correlation coefficients (r) of cellulose digestion *in vitro* versus the several *in vivo* values (as listed above) were: (1) 0.669*, (2) 0.726*, (3) 0.716*, (4) 0.811**, (5) —0.078, (6) 0.499, (7) 0.801**, respectively. Whereas the relationship between *in vivo* and *in vitro* cellulose digestion was not significant when all forages were considered, the relationship was highly significant ($r=0.901^{**}$) for the grass hays. The relationship between TDN estimated from anthrone carbohydrate digested *in vitro* and actual TDN was significant ($P<.05$). No significant relationship was found between DLN (*in vitro*) and TDN (*in vivo*).

179. UTILIZATION OF NITRATED AND UN-NITRATED FORAGES AT TWO STAGES OF MATURITY BY WASHED SUSPENSIONS OF RUMEN MICRO-ORGANISMS. O. Glenn Hall, Julius Barth and C. S. Hobbs, *University of Tennessee.*

Washed suspensions of rumen microorganisms were used in a series of experiments to compare utilization *in vitro* of nitrated (120 lb. N per acre) and un-nitrated forages at two stages of maturity. Sweet Sudan, Piper Sudan, German millet and Gahi—1 pearl millet were grown under similar conditions on replicated plots. Samples of the forages were obtained when the grasses attained a height of 20 in. (pasture stage) and 54 in. (hay or silage stage). Washed rumen microbes were suspended in a $NaHCO_3$ solution and added to fermentation flasks containing the forages as the sole source of nutrients. Cellulose digestion over a 24-hour fermentation period was used as a response criterion. When cut at the pasture stage the un-nitrated Sudans were utilized to a greater extent ($P<.01$) than the millets. At this stage of maturity, N fertilization did not significantly affect the utilization of the millets and Piper Sudan, whereas it had a marked negative effect ($P<.01$) on the utilization of Sweet Sudan. At the hay stage, differences in utilization were not significant regardless of nitrogen treatment. Maturity had a highly significant negative effect on utilization of the forages except German millet and nitrated Sweet Sudan. Addition of Ky. Bluegrass ash improved ($P<.01$) utilization *in vitro* of German millet. The influence of the ash from other grasses upon cellulose digestion *in vitro* was also determined.

180. TWENTY-FOUR PATTERN OF RUMEN VOLATILE FATTY ACID ACCUMULATION IN SHEEP FED AN ALL-HAY RATION WITH ADDITIONAL DATA INVOLVING THE USE OF TRIMETHYLALKYLAMMONIUM STEARATE. A. J. Sheppard, R. M. Forbes, and B. C. Johnson, *University of Illinois.*

Samples of rumen liquor were taken at one-hour intervals from two fistulated sheep fed an all-clover hay, mineral-supplemented ration. A column partition chromatographic technique was employed to separate and measure quantitatively butyric, propionic, and acetic acids. The first sample was taken just before a 30-minute, morning feeding period. A sharp rise in total acids occurred during the first hour, followed by a slower increase for the next 4 hours, reaching 12.22 mM/100 ml. The accumulation dropped off to 8.00 mM/100 ml. by nine hours. Then a sharp rise occurred, increasing total acids to 11.09 mM/100 ml. by 12 hours. This rise was followed by a gradual decrease to 6.30 mM/100 ml. by 24 hours as compared to 7.93 mM/100 ml. at zero hours. Each of the acids followed a similar pattern. No change in the relative molar ratio was noted with time. The relative molar ratio was 10.36% butyric, 18.44% propionic, and 71.17% acetic. When trimethylakylammonium stearate was added to the basal ration, a highly significant decrease in total acids as well as in individual acids was observed. However, if the total acid at zero time was substracted from the total acid accumulation with time, the presence of trimethylalkylammonium stearate made no difference.

181. LIGNIN AND METHOXYL GROUPS AS RELATED TO THE DECREASED DIGESTIBILITY OF MATURE FORAGES. George V. Quicke and Orville G. Bentley, *Ohio Agricultural Experiment Station.*

In an attempt to explain the decreased digestibility of cellulose in forages of advancing maturity, a study was made of the lignin and methoxyl content of two brome grass hays, two orchard grass hays and four timothy hays which were cut at different stages of maturity. The lower digestibility *in vitro* of the second stage orchard and brome grass hays relative to that of the less mature first stage could not be fully explained in terms of proximate composition or lignin content. In contrast, decreasing

cellulose digestibility (*in vitro*) in the case of the four timothy hays, did appear to be related to lignin content and especially to acid-insoluble lignin expressed as a percentage of total lignin. When the acid-insoluble lignin of the brome and orchard grass hays was expressed as a percentage of total lignin, the percentage acid-insoluble was higher in the brome grass hays than in the orchard grass hays, showing an association between higher acid-insoluble lignin values and decreased cellulose digestibility. It was also observed that the level of "non-lignin" methoxyl in the brome grass hays was almost double that in the orchard grass hays. It is concluded that in the mature brome and orchard grass hays studied, the differences in the lignin content of hays cut at different stages are too small to account for the observed differences in the digestibility of the cellulose.

182. EFFECT OF GRINDING ON THE VOLUNTARY CONSUMPTION AND DIGESTIBILITY OF EARLY VS LATE CUT CLOVER AND TIMOTHY HAYS, E. W. Crampton, L. E. Lloyd and S. E. Beacom, *Macdonald College (McGill University) Canada.*

Previous work at this laboratory has shown that the extent of voluntary consumption of different species of forages by sheep shows promise as an index of the feeding value of these forages. It is postulated that rate, or ease of digestion, rather than extent of digestion, is a factor regulating the disappearance of forage from the digestive tract and thus controlling appetite, or voluntary intake of forage. Extent of voluntary consumption of a forage may then serve as a measure of its ease of digestibility and of its feeding value. This raises the problem of determining the factors affecting the rate of digestibility of forages. In each of two digestibility trials, four lambs were fed early and late cuts of both Timothy and Red Clover in rotation. In one trial the forages were fed chopped, in the other they were fed ground and moistened. The four forages stood in the following relative positions with respect to voluntary intake of dry feed: Early Cut Clover 152, Late Cut Clover 139, Late Cut Timothy 103, Early Cut Timothy 100. The difference between cuts of Timothy are probably not significant. Grinding, however, uniformly increased the consumption of each of the feeds about 50 to 60%, and the digestible daily caloric intake some 40–50%.

183. EVALUATION OF PASTURE SWARDS BY DETERMINING THROUGH USE OF CHROMOGENS-CHROMIC OXIDE THE SEASONAL VARIATIONS IN DRY MATTER INTAKES AND DIGESTIBILITIES BY YEARLING BEEF STEERS. W. Brady Anthony, Paul F. Parks, E. L. Mayton and W. R. Langford, *Alabama Polytechnic Institute.*

Chromic oxide and plant chromogens techniques were used in combination to estimate forage digestible dry matter intakes of yearling steers grazing swards of lespedeza sericea (LS), white clover-dallis (CID), alfalfa-orchard (AO) and crimson clover-coastal bermuda (CrCo). Intake measurements were made at 28-day intervals for complete grazing seasons. For the first test year, average daily digestible dry matter intakes for the entire grazing season were 8.68, 8.16, 8.89 and 6.77 lb., respectively, for LS, CID, AO and CrCo swards. For the second test year, comparable values were 8.69, 9.54, 8.95 and 8.11. For the first test year, accumulated season totals of digestible dry matter consumed per acre for the several swards were appreciably different from per acre totals of TDN calculated by use of constants for maintenance and live weight gain. The two measures resulted in almost the same acre values for the second test year and either method might have been used for estimating effective nutrient yields for the several swards. Forage protein digestibility data (selective grazing bias in all values) revealed relative significant inferiority of LS protein. Cattle grazing LS consistently excreted relatively large amounts of fecal protein. Digestibility coefficients were lowest for LS.

184. DETERMINATION OF ESTROGENIC ACTIVITY IN FRESH AND DRIED FORAGES. E. M. Bickoff, A. N. Booth, A. P. Hendrickson, A. L. Livingston, and R. L. Layman, *Western Regional Research Laboratory USDA.*

In connection with studies on the isolation of the plant estrogen, coumestrol from ladino clover (Science *126,* 969 [1957]), a bioassay for estrogenicity in the plant was developed. Since it was found that dehydration lowers the apparent estrogenic activity of a forage, the plant material is processed for assay without drying. Fresh clover is harvested and rapidly macerated in a mechanical blendor with acetone to extract the estrogens. The aqueous-acetone extract is filtered, concentrated under vacuum to remove most of the water, and then redissolved in a minimum of acetone. Dehydrated or field-dried plant material is ground to 40 mesh and extracted with acetone for 24 hours in a Soxhlet apparatus. In either case, the acetone extract is uniformly incorporated into the control diet and the solvent removed. A preliminary extraction with chloroform is employed to remove impurities which may interfere with the bioassay. Estrogenic activity is determined by feeding the acetone extract of the plant material to immature female mice, 18–20 days old, weighing 8–10 gm. at the start of the test. For the bioassay, mice in groups of five, are fed the test diet *ad libitum,* until an average of 10 gm. per mouse has been consumed. This usually requires from 6 to 8 days. The animals are then sacrificed and the weights of the freshly excised uteri are determined. Positive and negative controls are included in each assay. Activity in plants is evaluated in terms of stilbestrol or coumestrol equivalency.

185. GROWTH AND CARCASS CHARACTERISTICS OF WESTERN LAMBS GIVEN STILBESTROL IMPLANTS WITH AND WITHOUT GRAIN FEEDING ON WINTER TEMPORARY PASTURE AND DRYLOT. D. M. Baird, H. C. McCampbell, W. E. Neville, Jr. and O. E. Sell, *Georgia Experiment Station.*

Eighty western type lambs (Hamp. X Ramb.) averaging approximately 68 lb. were divided into four main treatment groups of (1) drylot (2) temporary pasture (oats, ryegrass and crim. clover) (3) temporary pasture+grain feeding and (4) rescue grass. Each treatment was subdivided with half of each treatment receiving a 3 mg. implantation of stilbestrol. Lambs were individually removed for slaughter upon reaching 105 lb. weight. The A.D.G.'s (obtained by fitting constants) for the four main treatments were (1) 0.50, (2) 0.44, (3) 0.50 and (4) 0.45 lb. These differences were not significant. Daily gains similarly obtained for the non-implanted and implanted lambs were 0.38 and 0.57 lb., respectively. This difference was significant ($P<0.01$). The only significant ($P<0.01$) effect on carcass grade was a feeding method x hormone interaction. The area of the loin eye was not significantly different for any of the treatments; however, the fat covering over the loin, for similar weight lambs, was significantly ($P<0.01$) less for the implanted lambs when compared with the non-implanted. Rescue grass, a weak perennial with annual re-seeding habits, appeared as productive as the temporary forage. Pasture feeding reduced the cost of production when compared with the drylot method of feeding.

186. THE INFLUENCE OF ORAL ADMINISTRATION OF STILBESTROL, PENICILLIN, AND AUREOMYCIN ON STEERS FED ALFALFA SOILAGE. W. W. Heinemann, M. E. Ensminger and H. H. Fanelli, *State College of Washington.*

A total of 72 yearling steers were full fed alfalfa soilage from about May 1 to July 1; 36 in 1957 and 36 in 1958. They had been wintered 155 days to gain about 1.3 ($\pm$0.12) lb. daily. Alfalfa soilage produced a daily gain of 1.50 lb. each year. Starting about July 1 each year the cattle were given a half ration of barley (2 parts) and dried beet pulp (1 part) in which was included (1) stilbestrol at a level to supply

10 mg. daily per steer, (2) Aureomycin, 75 mg. daily per steer, (3) penicillin, 32 mg. daily per steer, (4) a combination of stilbestrol and Aureomycin at above levels, (5) a combination of stilbestrol and penicillin at above levels, (6) no additives. Each treatment was given to six steers fed in lots of three animals each year. At all times alfalfa soilage was fed at the level eaten by the lot of steers with the smallest appetites. In 1957 soilage feeding was discontinued October 12 and alfalfa hay was substituted until the cattle were slaughtered December 5. Lowest gains were made by the controls, 2.06 lb. ($P<0.01$). Highest gains were made by cattle on treatment (4), 2.80 lb. ($P<0.01$). No significant difference existed among gains by the cattle on the other treatments. Feed efficiency was significantly improved by all the additives. Nearly 78% of the stilbestrol cattle graded Choice, more than any other treatment. No differences due to treatments could be found in dressing percentage, liver weights or size of the bulbo-urethrals. Bloat was controlled by penicillin; it was a serious trouble among all other cattle.

187. CATTLE GAINS AND VEGETATION CHANGES AS INFLUENCED BY GRAZING TREATMENTS ON CRESTED WHEATGRASS OVER A TEN-YEAR PERIOD. Lorin E. Harris, Neil C. Frischknecht and Robert J. Raleigh, *Utah Agricultural Experiment Station, Logan, and Intermountain Forest and Range Experiment Station, Ogden.*

An experiment at Benmore, Utah, involves grazing of cattle at three intensities and four methods, replicated twice, on twenty-four 100-acre pastures of crested wheatgrass. The pastures are grazed for approximately 60 days in the spring and 40 to 50 days in the fall when regrowth is adequate. Cattle were classified as follows: yearlings, dry cows, cows calving in pastures, cows having calves when entering pastures, and calves entering pastures. Results for spring grazing from 1948 to 1957 are as follows: Light (50% utilization), and moderate (65% utilization) grazing produced significantly more daily individual gain than heavy grazing (80% utilization) 2.85, 2.70, and 2.15 lb. gain per head per day for all cattle, respectively. There was a trend for the removed 10 days early treatment to produce more daily individual gain than the continuous, 10 day deferred, and rotation treatments (2.76, 2.46, 2.55, and 2.50 lb. daily gain, respectively). At the end of 10 years, the moderate grazed pastures produced more total gain and digestible energy than the light and heavy grazed pasturs. Total average gain per acre per year for the methods were: rotation, 42 lb.; continuous, 41 lb.; removed 10 days early, 39 lb.; and 10 days deferred, 38 lb. Cows with calves gained less in heavy grazed pastures than the other classes of cattle. Crested wheatgrass plants have increased in all pastures. Heavy grazing and, to a lesser extent, moderate grazing resulted in declines in plant numbers from 1954 to 1956, whereas under light grazing, plant numbers continue to show an increase. Rabbitbrush yields declined from 1952 to 1956, perhaps because of the below-average precipitation, as follows: 53% in lightly grazed pastures, 40% in moderately grazed pastures, and 23% in heavily grazed pastures. Undoubtedly, a vigorous grass stand minimizes increase of brush. Unlike yields of rabbitbrush, yields of sagebrush increased from 1952 to 1956: 6.2% on lightly grazed pastures, 32% on moderately grazed pastures, and 79% on heavily grazed pastures. For best results it is recommended that crested wheatgrass pastures be grazed at a moderate intensity (60% utilization).

188. THE NUTRITIVE VALUE OF ALFALFA HAY HARVESTED AT THREE STAGES OF MATURITY. J. C. Smith, R. W. Hemken, R. F. Davis, and A. M. Decker, *University of Maryland.*

First cutting alfalfa hay was harvested at one-tenth bud, full bud, and one-half bloom for three successive years and fed to lactating cows. The hays were fed *ad libitum* as the only source of nutrients with the exception that the cows had free access

to trace mineralized salt. Each year 12 cows were divided into groups of three and assigned at random to 3 x 3 latin squares. Periods were 4 weeks in duration. Milk production, butterfat test, feed consumption, and body weights were obtained. The three-year averages for average daily 4% FCM production for the hay harvested at one-tenth bud, full bud, and one-half bloom were 30.9 lb., 28.5 lb., and 26.9 lb., respectively. The average daily hay consumption averaged 38.9 lb., 38.1 lb., and 36.1 lb., and the average daily body weight changes were —0.21 lb., —0.05 lb., and —0.25 lb., respectively, for the one-tenth bud, full bud, and one-half bloom hays. Milk production and hay consumption differences were highly significant for the first and third year of the experiment. Difference in body weight changes were not significant.

189. EFFECT OF STAGE OF MATURITY ON THE CHEMICAL CHARACTERISTICS AND SUBJECTIVE SCORE OF SORGHUM SILAGES. F. G. Owen and O. J. Webster, *University of Nebraska.*

Six varieties of forage sorghums were evaluated by a subjective score and by proximate chemical analysis at six stages of maturity. Four hybrid sorghums, two sterile (301FS and 303FS) and two open pollinated (301FOP and 303FOP) were compared with two standard varieties (Rox and Atlas). Chemical values for the medium dough, hard dough, and mature stages were averaged for comparison of varieties. The sterile varieties contained a lower percent of dry matter, crude protein (CP), NFE, and calculated TDN than the open pollinated varieties. On the dry basis the sterile hybrids contained slightly more protein and crude fiber, but less NFE than open pollinated hybrids. Compared to the hybrids, the standard varieties contained a lower percent of CP on the wet basis; and on the dry basis, were lower in CP but higher in NFE and TDN. With advancing maturity from the bloom to the mature stage: yields increased from 4,711 to 7,855 lb. dry matter/acre; crude protein increased from 2.15 to 2.48%; and TDN from 12.0% to 17.0%. As a percent of dry matter, the CP decreased and the NFE increased slightly with advancing maturity, but TDN and other components remained practically unchanged. Silages were scored by five judges on the basis of grain content, color and odor. These scores were significantly correlated with the calculated TDN value of the silages.

190. SOME CHEMICAL CHANGES ACCOMPANYING SILAGE FERMENTATION. M. E. McCullough and Ann R. Stasch, *Georgia Experiment Station.*

Studies were conducted on the changes in chemical composition of, and nutrient losses from, oat silage preserved in eight 20-ton upright silos. One silo each of sudan grass, barley, corn and a dough stage oat was also included in part of the study. On the basis of the observed variance in dry matter and pH measurements, a sample from each 6% of the silage was necessary to measure significant differences of 0.1 pH and 1.5% dry matter between silos. Mean changes in percentage proximate composition of forage in the silo were: crude protein, +0.83, ether extract, +1.71, crude fiber +4.02 and N.F.E. —5.64. The respective correlations between forage and the resulting silage composition were: crude protein, 0.936, ether extract, 0.574, crude fiber, 0.727 and, N.F.E., 0.697. This indicated that the fat and carbohydrates were subject to forage fermentation changes while the other components were affected by non-fermentation losses. The overall mean conversion rate of hydrolyzable carbohydrates to organic acids was 1:2.27. The use of ground snap corn as a preservative (200 lb./ton) reduced this rate to 1:1.96 while sodium metabisulfite (8 lb./ton) increased it to 1:2.87. Silages with a lactic acid content below 7% (dry matter basis) had a conversion rate of 1:2.80 and those above 7% a rate of 1:1.87. The effect of preservative on recovery of hydrolyzable carbohydrates at stage of cutting was, boot stage with snap corn, 36%, $Na_2S_2O_5$, 7%; prebloom stage, snap corn, 49%, $Na_2S_2O_5$, 36%; and milk stage, no preservative, 23% and $Na_2S_2O_5$, 34%.

191. THE EFFECT OF LEVEL OF PROTEIN INTAKE AND ALFALFA MEAL ON REPRODUCTION AND GAINS IN BEEF COWS. H. G. Witt, A. C. Warnick, M. Koger and T. J. Cunha, *University of Florida.*

Eighteen 8-year-old and eighteen 3-year-old Brahman crossbred cows, pregnant for 6 months or more, were divided into three groups and fed a basal ration of Pangolagrass hay free choice. Group I received a ration containing 100% of the protein requirements (N.R.C.), Group II received the 100% of protein intake which included 3 lb. daily of alfalfa meal, while Group III received only 50% of the protein requirements with no alfalfa. Cows were on the rations 84 days before breeding and 84 days during the breeding season. The average weight losses during the 168 days for all cows in Group I was 38 lb.; Group II was 15 lb.; and Group III was 172 lb. Daily gains of calves from the 8-year-old cows averaged 0.31 lb. more than calves from the 3-year-old cows. Hay intake was reduced in both 3- and 8-year-old cows on the low protein ration. The interval from calving to first breeding in 3-year-olds was 91, 56 and 160 days for Groups I through III, respectively; and in 8-year-olds was 64, 64 and 96 days for Groups I through III, respectively. The percentage of lactating females, pregnant 45 days or more, in the 3-year-olds was 17, 33 and 0 percent in Groups I through III, respectively; and in the 8-year-olds was 83, 80 and 33 in Groups I through III, respectively. Cows failing to show a postpartum estrus on the low protein ration also failed to ovulate. Approximately 40% of the breedings in 3-year-old cows were anovulatory.

192. CESSATION OF ESTRUS AND OVARIAN ACTIVITY IN A GROUP OF BEEF HEIFERS ON EXTREMELY LOW LEVELS OF ENERGY AND PROTEIN. J. Bond, J. N. Wiltbank and A. C. Cook, *Beef Cattle Research Branch, A.R.S. USDA.*

Nine heifers of beef and dual-purpose breeding, having normal estrous cycles, were divided into two groups: Group I, 6 heifers (av. wt. 671 lb.) was fed 5 lb. daily (3.26 lb. T.D.N., 0.94 lb. digestible protein) for 42 days and Group II, 3 heifers (637 lb.) was fed 4.4 lb. daily (2.80 T.D.N., 0.26 lb. D.P.) for 77 days. At the end of these periods all heifers were still cycling. The heifers of Group I maintained their weight while Group II heifers lost an average of 66 lb. The feed was decreased to supply 2.41 lb. T.D.N., 0.20 lb. D.P. for Group I and 2.50 lb. T.D.N., 0.08 lb. D.P. for Group II. The heifers were fed this ration until they ceased to cycle. From beginning of experiment to cessation of estrus Group I lost 131 lb. (Range —180 to —52) in an average of 136 days and Group II lost 108 lb. (—141 to —50) in an average of 130 days. After a heifer ceased to cycle, she was fed 6.6 lb. of concentrate (4.28 lb. T.D.N., 0.55 lb. D.P.) and 3 lb. of hay (1.47 lb. T.D.N., 0.09 lb. D.P.) in dry lot for an average of 152 days. They received 3 lb. of concentrate (1.94 lb. T.D.N., 0.25 lb. D.P.) on pasture in addition to the forage for the remainder of the experiment. The average time and gain of heifers from cessation of estrus to its re-establishment was 228 days (240 to 199) and 223 lb. (286 to 205) for Group I and 179 days (275 to 82) and 125 lb. (193 to 44) for Group II.

193. EFFECT OF CONDITION ON REPRODUCTION IN SWINE. B. T. Dean, V. B. Reddy, J. F. Lasley and L. F. Tribble, *University of Missouri.*

The effects of condition (fatness) during the gestation period on the reproductive performance of gilts was studied. The condition of the gilts was determined by the backfat probing technique. The gilts were probed at breeding, mid-gestation, farrowing and 6 weeks after farrowing. Ten Hampshire and six Duroc gilts were divided equally into two lots. The gilts in lot 1 were fed to gain approximately one lb. per day during the gestation period, while those in lot 2 were fed to gain one-half lb.

All of the gilts in lot 1 maintained or gained in condition, while all gilts in lot 2, except 2, lost in condition during gestation as measured by the backfat probe. There was no difference in number of pigs farrowed between the Hampshire gilts in the two lots. They averaged 9.2 pigs per litter in each lot. The Duroc gilts in lot 2 farrowed an average of 11 pigs as compared to 6 for those in lot 1. The gilts in lot 2 weaned 6.9 pigs per litter as compared to 4.4 for those in lot 1. Thirty additional gilts were probed to obtain a larger number for correlation analysis of the effect of condition on number of pigs farrowed. The gain or loss in condition of the 46 gilts from breeding to farrowing as measured by the backfat probe was correlated with the number of pigs farrowed. A significant negative correlation ($r = -.31$ $P < .05$) was obtained.

194. THE EFFECT OF GLUCOSE FEEDING ON OVULATION RATE IN CHESTER WHITE GILTS. D. R. Zimmerman, H. G. Spies, H. L. Self and L. E. Casida, *University of Wisconsin.*

The nutrient intake of 20 Chester White gilts was limited to approximately two-thirds of a full feed from 154 days of age until day-8 of their second estrual cycle following puberty. The gilts were then randomly assigned to two experimental groups (flushed and non-flushed) in equal numbers and hand-fed a basal ration twice daily at the rate of 2½% of their individual body weights per day. Flushing was accomplished by feeding glucose at the rate of 1% of their individual body weights per day in addition to the basal ration from day-8 of their second estrual cycle to slaughter (3–4 days following third estrus). Blood samples were taken immediately before and one hour after the a.m. feeding on the ninth day of the glucose feeding period. The increases in blood sugar level between the prefeeding and postfeeding bleedings averaged 9.4 mg.% greater than unflushed ($P > 0.05 < 0.10$). There was no indication of a difference in the fasting sugar levels (14–16 hours after feeding) between the two groups. Flushed gilts gained more rapidly than unflushed gilts (1.6 vs. 1.0 lb./day, $P < 0.01$). At post-mortem the ovaries were removed and a larger number of corpora lutea was found in the flushed than in the non-flushed gilts (11.8 vs. 9.7, $P < 0.01$).

195. REPRODUCTION, PLACENTATION AND PRENATAL DEVELOPMENT IN SWINE AS AFFECTED BY NUTRITIONAL ENVIRONMENT. E. S. E. Hafez, *State College of Washington.*

Palouse gilts were divided into two groups; one group was full fed from weaning to 150 lb.; the other group was fed only 70% this amount. After six generations, one-half of the pigs in each group were shifted to the other plane of nutrition, thus forming four groups: high-high (HH), low-low (LL), low-high (LH) and high-low (HL). F_{10} gilts were slaughtered 38 days post-coitum; the endocrines, embryos and placentae were weighed. Puberty age in LH (229.3 days) was higher than other groups. Puberty weight was greater and number of silent heats and services/conception were higher in HH and LH than LL and HL. Puberty weight was 4 times the weaning weight; this ratio was not affected by nutrition. Ovulation rate in HH (15.5) was significantly higher than LH, LL and HL. Thyroid weight in HH (9.69 gm) and in LH (15.25) was heavier than LL and HL. Implantation occurred in 77.27, 72.72, 64.50 and 48.18% of the ova in LL, HL, HH, and LH, respectively. There were no significant differences in weight of corpus luteum, pituitary, adrenals, embryo or amniotic fluid or length of oviduct or crown/rump. The weight of allantoic fluid or uterus was greater in HH and LH than in LL and HL. Maximum variation within the same litter was in the allantoic fluid, followed in order by placental membranes, amnion, embryo weight, then crown/rump. These variations were not related to sequence in horn or plane of nutrition. Causes of prenatal mortality were classified.

196. FURTHER STUDIES ON THE EFFECTS OF NITRATE UPON REPRODUCTION AND VITAMIN A STORAGE WITH RATS AND SWINE. G. B. Garner, B. L. O'Dell, Patty Radar and M. E. Muhrer, *University of Missouri.*

A previous report had shown that 1.0–2.0% KNO_3 in the ration of bred female rats would not allow normal reproduction. In this study, four lots with two sows in each lot were placed on a practical ration containing 0.0, 0.5, 1.0, 2.0% KNO_3, respectively, 35 days after breeding. They were fed 6½ lb. dry feed for the first 14 days of the experiment, resulting in an average daily gain of 2.46 lb./head/day. Feed was then reduced to 5.0 lb./head/day until parturition. During lactation it was increased to 10 lb./head/day. Serum nitrate levels were determined. Control serum nitrate levels were 1–3 mg. %. Serum nitrate increased with increasing amounts of nitrate in the ration to 16 mg. %. Litter size was not affected; however, livability and number of strong pigs appeared to decrease with higher levels of nitrate. Milk production apparently was not reduced as had been found with 1–2% KNO_3 rations for dairy cattle. Serum from dead pigs indicated an elevated serum nitrate corresponding to dams rations. Only in one litter (2% level) was there evidence of a vitamin A deficiency. Using weanling rats, the depletion of vitamin A stored in livers was studied. The depletion appeared to be more rapid with NO_3- and NO_2-containing rations. Histological studies fail to reveal a true vitamin A deficiency, in spite of a deficiency syndrome.

197. REPRODUCTIVE PERFORMANCE OF RATS FED ARSANILIC ACID. P. H. Sammelwitz and D. E. Becker, *University of Illinois.*

Arsanilic acid (A.A.) at two levels (0.01% and 0.02%) were fed to female rats of various ages for varying intervals in an attempt to determine its effect on reproductive performance. The A.A. feed was available to the rats ad. lib. at all times. The experimental procedure consisted of (a) feeding mature females (b) feeding young rats weaned from mothers which received the normal stock ration and (c) feeding young rats weaned from A.A. fed mothers. Sixty-five mature females were randomly placed into groups receiving 0.00%, 0.01% and 0.02% A.A. for 15 days prior to cohabitation with males. They were autopsied at the 20th day of gestation and the number of corpora lutea (C.L.), implantation sites and fetuses were counted. There was a significant decrease in ovulation rate at the 0.02% A.A. level ($P=.001$). Since implantation rate was unaffected by this level of A.A., a significant increase in reproductive efficiency also occurred ($P=.001$). When female rats which had received the various levels of A.A. feed from weaning (21 days of age) were bred, no significant differences were obtained in ovulation rate, although implantation rate was improved. Females weaned at 21 days from A.A. fed mothers were continued on A.A. feed throughout their reproductive life. A significant reduction in ovulation rate occurred at both levels of A.A. feeding ($P=.01$), while implantation rate was progressively improved by increasing levels. This accounted for a similar progressive improvement in reproductive efficiency (% C.L. as viable fetuses).

198. THE EFFECTS OF FOUR SYNTHETIC CORTICOIDS ON LEUCOCYTES, BLOOD GLUCOSE, AND PLASMA SODIUM AND POTASSIUM IN THE COW. Dennis D. Goetsch, L. E. McDonald, and George Odell, *Oklahoma Agricultural Experiment Station.*

Reports have shown that desaturation, fluorination, or methylation of hydrocortisone will markedly increase the glucocorticoid and mineralocorticoid activity of this compound in laboratory animals; however, little is known about their activity in large animals. A randomized complete block design was used in which each one of eight lactating Holstein cows was injected with one of the following: 50 or 100 mg.

of delta-l-hydrocortisone (prednisolone), 25 or 100 mg. of 9 alpha fluorohydrocortisone, 25 or 100 mg. of delta-1, 9 alpha fluorohydrocortisone (9 alpha fluoro prednisolone), or 25 or 100 mg. of 6 methyl hydrocortisone. This procedure was replicated six times with two-week intervals between replications. The greatest elevation in blood glucose was produced by 100 mg. of delta-1, 9 alpha fluorohydrocortisone. Delta-l-hydrocortisone at the 100 mg. level also caused a marked rise in blood glucose values. Twenty-five mg. of delta 1, 9 alpha fluorhydrocortisone and 100 mg. of 9 alpha fluorohydrocortisone were similar in their blood sugar elevating properties. Only slight glucocorticoid activity was exhibited by 25 mg. of 9 alpha fluorohydrocortisone and 50 mg. of delta-l-hydrocortisone, whereas methylation at either dosage level did not produce any changes in blood glucose values. All compounds at all levels produced a leucocytosis; delta, 1, 9 alpha fluorhydrocortisone was the most potent in this respect. The increase in leucocytes was due to an increase in circulating neutrophils. The number of circulating lymphocytes remained unchanged whereas an eosinopenia resulted from the injected corticoids. There were no significant changes in plasma sodium or potassium levels from any of the compounds at the dosages given.

199. EFFECT OF ARTIFICIAL INSEMINATION OF GILTS WITH SEMEN STORED FOR ½ HOUR VS. 72 HOURS. P. J. Dziuk, *University of Illinois.*

Experimental animals were 40 crossbred gilts about 6 months old and 5 Duroc boars about 1 year old. Semen was collected from each boar at 72-hour intervals and immediately added to an egg yolk-glucose-sodium bicarbonate diluter with added antibiotics. Semen was diluted 1:2 and slowly cooled and held at 7° C. All gilts were bred once on the first day of estrus with 100 ml. of diluted semen. Groups I and II were inseminated with freshly diluted semen and killed 4 and 35+ days later, respectively. Groups III and IV were inseminated with semen stored for 72 hours and killed 4 and 35+ days later, respectively. In group I, 7 of 8 (88%) gilts contained fertilized ova. Seventy percent of the ova recovered from the 7 pregnant animals were fertilized. In group II, 7 of 10 (70%) gilts were pregnant and 66% of the corpora lutea in these 7 were represented by living fetuses. In group III, 4 of 11 (36%) gilts contained fertilized ova and 49% of the ova recovered from the 4 pregnant gilts were fertilized. Group IV had 2 pregnant animals out of 11 (18%) with 37% of the corpora lutea of the 2 pregnant gilts represented by living fetuses. These data indicate that under the conditions of this experiment, storage of semen for 72 hours reduces the conception rate, number of ova fertilized and number of fetuses as compared to immediate insemination following collection and dilution of the semen.

200. EFFECT OF PITOCIN ON FERTILITY IN GILTS ARTIFICIALLY INSEMINATED WITH A LOW SPERM CONCENTRATION AND SEMEN VOLUME. F. W. Stratman, H. L. Self and V. R. Smith, *University of Wisconsin.*

Seventy-three gilts of mixed breeding and unknown sexual age (number of pre-experimental estrous cycles unknown) artificially inseminated with approximately 2.5 billion sperm suspended in a milk diluent were assigned randomly to either a control group, a group receiving 10 I.U. pitocin intrauterine, or a group receiving 10 I.U. pitocin intravenously. The percent of ova recovered that were fertilized, the percent of gilts conceiving and the three-day post-breeding litter size was obtained. The mean fertility for the control, intrauterine, and intravenous groups was 58.3%, 44.7% and 71.5% ($P<0.01$). The mean conception rate was 92.1%, 85.7% and 95.8%, respectively. There was also a significant difference among boars ($P<0.05$). The litter size at 3 days post-breeding was 5.6 for the control, 5.0 for the intrauterine group and 6.8 for the intravenous group. These values were not significantly different. However, within boars the intravenous group was always higher than the other two groups in fertility and in three-day litter size.

201. SOME FACTORS AFFECTING THE SEMEN OF EGYPTIAN CATTLE AND BUFFALOES. M. M. Oloufa, A. L. Badreldin and A. A. Sayed, *Cairo University, Egypt.*

The development of sexual behavior was studied in five buffalo bull-calves ranging in age from 8 to 14 months. The transition period from the infantile stage to the sexually functioning one averaged 23 weeks. Buffalo bulls reached maturity at the mean age of 81 weeks; however, they should not be used for heavy service before they are 2 years old. Four native and three buffalo bulls were used to study the effect of season on their semen. The quality of semen was higher in summer than in the other seasons of the year. The second ejaculate was also better in most of its characteristics than the first one. Sixty semen collections were taken from 10 mature native and buffalo bulls for the physical and chemical analysis. The general picture of the physical and chemical characteristics of their semen resembled that of the European breeds of cattle. The effect of the frequency of collection on eight native and buffalo bulls showed that semen quality declined when collection was done three times a week for 13 weeks as compared to semen collection once weekly. It was also found that buffalo's milk was better than cow's milk for diluting semen; and whole milk was preferred over skim milk in this respect.

202. A COMPARISON OF THE FERTILITY OF BULL SEMEN EXTENDED IN YOLK-CITRATE AND GLYCERINATED, HEATED, HOMOGENIZED MILK. J. E. Johnston, H. C. Kellgren, T. E. Patrick and J. O. Shelwick, *Louisiana State University.*

A field trial was initiated to compare the fertility level of bovine spermatozoa extended in yolk-citrate (YC) and heated, homogenized whole milk-glycerol (MG). The procedure as outlined by Almquist was followed for the preparation of the MG. Split ejaculates were extended at the rate of 10 million motile sperm per milliliter of each extender. Each extender was shipped alternately to two groups of technicians for 10 shipments. The majority of inseminations were performed with two-, three-, and four-day old semen. Non-return rates (60–90 days) for YC and MG were, respectively, 75.4 and 78.7%, at 2 days, 71.4 and 72.6% at 3 days, 62.6 and 69.2% at 4 days. The number of first services and the 60- to 90-day non-return rate for YC was 2,709 and 70.5% and for GH, 2,682 and 73.8%. These results indicated that the MG was more efficient than the YC after the third day. Further studies are in progress which will yield sufficient fertility data through the fifth day.

203. FACTORS AFFECTING REPLENISHMENT OF SPERM NUMBERS IN BULLS FREQUENTLY EJACULATED. N. L. VanDemark and R. E. Mauger, *University of Illinois.*

The effects of two levels of TDN intake (60 and 100%, based on the mid-point of Morrison's standards, 21st ed.) and the rate of sperm withdrawal on growth, the age of puberty, and the replenishment rate of depleted sperm reserves has been studied. Partial exhaustions (10 ejaculates in 90 min.) following an initial were repeated at 1, 4, 7 and 13-day intervals. The data were collected from measurements and partial exhaustions when the bulls were 12, 16, 20, 24, 28 and 32 months of age. The average body weight, height at withers, circumference of barrel, circumference of chest, testis measurements (length and width) *in situ* and semen characteristics of the two groups were compared. Throughout the experiment the underfed bulls lacked both skeletal size and flesh as compared to the controls. The underfed bulls were 8 months slower than the controls in reaching an appreciable semen producing ability. They were also 8 months behind the control bulls in reaching their mature sperm producing capacity. A comparison of body weight, testis size and total sperm ejaculated showed the underfed bulls at 20 months of age were 80%, 90% and 92%, respectively, of these measure-

ments on the control bulls at 12 months. These percentages changed to 98%, 98% and 91%, respectively, when the underfed bulls at 28 months were compared to the controls at 16 months. As the bulls in each group increased in age and weight, the rate of replenishment became more rapid for severely depleted sperm reserves.

204. THE USE OR FLUORESCENT DYES FOR STUDYING SPERM MOTILITY. N. L. VanDemark, R. Schorr and V. L. Estergreen, Jr., *University of Illinois.*

The observation and evalution of sperm in some diluents such as whole milk and yolk-phosphate have always presented a problem because of the opacity of these media. In an attempt to make the sperm more visible in such media, a number of fluorescent dyes were studied and the four found to be most satisfactory for sperm were Coriphosphin, Euchrysin 2, Acridine Orange and Akridingelb. The dye was dissolved in 0.9% NaCl, adjusted to pH 6.8 with 0.1N NaOH, filtered, and added to a sample of diluted semen to give a final concentration of dye to diluted semen of 1:10,000 to 1:40,000. Best fluorescence was obtained if this mixture was incubated for 15 min. in a water bath at 37° C. before examination. The stained sample was examined under the microscope using ultra-violet light provided by a mercury vapor lamp (GE AH4) fitted with an exciter filter (Corning No. 5113). A barrier filter (Corning No. 3484) placed in the eyepiece protected the eye from the u.v. rays. In semen diluted with an opaque media such as whole milk and examined in this manner, the spermatozoa were outstandingly visible with no interference from fat globules or other extraneous material, and motility evaluation was readily made. These dyes were non-toxic to the spermatozoa during the 15 min. incubation and caused only a slight reduction in motility after storage at 5° C. for 24 hours. Fluorescent staining has proved to be an effective method for evaluation of sperm in whole milk, yolk-phosphate or other diluents in which white light illumination does not allow good discrimination between sperm and media.

205. EFFECTS OF TREATMENT OF SEMEN WITH ANTIBODIES ON FERTILITY IN RABBITS. C. A. Kiddy, W. H. Stone and L. E. Casida, *University of Wisconsin.*

Heifers were immunized with rabbit semen. The immune sera (IS) from them, in high concentrations, caused tail-tail agglutination of rabbit sperm in contrast to a head-head type produced by normal sera (NS). Diluted rabbit semen (same concentration for each trial) was mixed with NS and IS approximately 15 minutes before being used for insemination. Normal serum did not affect fertilization. High concentrations of IS prevented fertilization but the fertilization rate increased as lower concentrations were used (173 females studied). Embryo survival percentage was estimated in the NS and IS groups by a comparison of the number of fertilized ova in a random sample of females killed at 28 hours after insemination with the number of surviving fetuses in a comparable group of females at 28 days. The average embryo survival percentage for 58 IS females was 38.2 compared to 53.1 for 59 NS females. The loss of whole litters was much more common in the IS group (23 females out of 58) than it was in the NS group (3 females out of 59). Resorbing embryos or placental sites were found in 17 of the 23 IS females. A significantly greater amount ($P<0.005$) of embryonic death occurred in the IS group. The mechanism by which the antibodies caused fertilization failure and embryonic death is not known. The effect on fertility could not be explained on the basis of the gross amount of sperm agglutination or any marked interference with sperm motility.

206. THE PROCESS OF PLACENTATION IN THE BOVINE. G. B. Marion and H. T. Gier, *Kansas State College.*

The reproductive tracts of 30 dairy cows pregnant from 15 to 38 days were utilized in this study. Considerable variation in the extent of embryonic membrane

development was noted between cows in the same stage of gestation. The dimensions presented represent the average rate of placental development. By 15 days the serosal vesicle, lined with endoderm, fills the cavity of the pregnant horn. The addition of a mesodermal layer results in the formation of a complete yolk sac 300 mm. long by 17 days. The embryo is dependent on uterine gland secretion diffusing through the unattached membranes until the 23rd day. The allantois, which first appears on the 23rd day, expands, as a turgid sac, to 20 mm. by the end of the 23rd day; to 80 mm. by day 25; and to 160 mm. by the 27th day. By day 34 the amnion fills the serosal vesicle. From a length of 500 mm. at 23 days, the yolk sac regresses to a remnant by 30 days. From the 23rd day until the formation of placentomes, fusion between the serosal ectoderm and maternal epithelium makes possible direct transfer of nutrients into the extraembryonic circulation. The development of villi is first noted at 29 days. As the placentomes develop, transfer of nutrients becomes localized, the intercaruncular attachment is lost, and a new intercaruncular uterine epithelium becomes established.

207. SOME SOURCES OF VARIATION IN CONCEPTION RATE AND PREGNANCY LOSS IN PAROUS HOLSTEIN COWS. S. E. Mares, A. C. Menge, W. J. Tyler and L. E. Casida, *University of Wisconsin.*

Data were analyzed from 346 parous cows for conception at first insemination and pregnancy loss to 151 days postbreeding as affected by sire-line and system of mating. Six sire-lines of the cow and four systems of mating of the insemination (potential embryo) were studied over a 6-yr. period. Cows were bred artificially at the first estrus after 75 days post-partum if in satisfactory breeding condition as determined by rectal palpation. Cows not returning to estrus by 35–41 days postbreeding were examined for pregnancy and palpable evidence of embryonic membranes was used as the criterion for conception. Of the 513 first inseminations, 58.3% resulted in conception, with a range of 48.8 to 77.5% for the sire-lines. The values for the systems of mating ranged from 36.8% for inbred inseminations of inbred dams to 65.7% for outbred inseminations of outbred dams, while inbred and outbred inseminations of outbred and inbred dams, respectively, were intermediate and approximately equal. Analyses using angle transformations showed a sire-line effect ($P<0.01$) as well as an effect ($P<0.05$) due to the interaction of sire-line with system of mating. Seventeen percent of all diagnosed pregnancies were lost before 151 days postbreeding during the course of this study. System of mating was found to have an effect ($P<0.05$) on pregnancy loss with the greater loss occurring in outbred and inbred embryos of inbred dams (26.0 and 27.4%) as compared to outbred and inbred embryos of outbred dams (13.7 and 12.9%).

208. EFFECT OF OVARIECTOMY ON THE BACTERICIDAL ACTIVITY OF RABBIT UTERI. H. W. Hawk, G. D. Turner and J. F. Sykes, *USDA, ARS, Dairy Cattle Research Branch.*

Ovarian hormones influence the bactericidal action of the uterus. Uteri of estrous rabbits show greater bactericidal activity than uteri of pseudopregnant rabbits as early as 4 hours after experimental uterine inoculation. One uterine horn in each of 9 estrous rabbits, 9 pseudopregnant rabbits and 9 rabbits ovariectomized 15 days previously was ligated at each end and inoculated with approximately 200 million *Escherichia coli* to determine the bactericidal activity of ovariectomized rabbit uteri in relation to the others. Mean log numbers of *E. coli* recovered 4 hours later were as follows (corresponding numbers in parentheses): estrous rabbits, 5.48 (302,000); ovariectomized rabbits, 5.74 (550,000); pseudopregnant rabbits, 7.84 (69,200,000). The mean numbers recovered from the estrous and the ovariectomized rabbits were each significantly less than that from the pseudopregnant rabbits ($P<0.01$ for each comparison). Thus the uterine defense mechanism of both ovariectomized and estrous rabbits was much more effective than that of pseudopregnant rabbits, suggesting that the differential bactericidal activity of estrous and pseudopregnant rabbit uteri during the

early stages of *E. coli*-induced infections may be due more to an inhibitory effect of progesterone on the uterine defense mechanism than to a stimulatory effect of estrogen.

209. THE INFLUENCE OF PROGESTERONE TREATMENT ON POST-PARTUM REPRODUCTIVE ACTIVITY IN BEEF CATTLE. W. D. Foote, E. R. Hauser and L. E. Casida, *University of Wisconsin.*

The effect of a single post-partum injection of progesterone on the intervals from calving to involution of uterus, first ovulation, and first heat were studied in 44 Angus and 18 Shorthorn cows. The animals were paired within breeds before calving on the basis of relationship, parity, and month of calving. One cow of each pair received 1 mg. progesterone per lb. body weight subcutaneously in a starch emulsion on the 14th day after calving. The other member of each pair remained untreated. Treatment had no significant effect on the interval from calving to involution of the uterus in either breed. The treated and untreated averages were 41.4 and 40.9 days respectively for the Angus groups and 42.6 and 42.6 for the Shorthorn. The average interval from calving to first ovulation was significantly longer in the treated than in the untreated Angus group (60.7 vs. 35.9 days). The trend was in the same direction for the Shorthorns but it was statistically non-significant (62.1 vs. 55.2 days). The average intervals from calving to first heat for treated and untreated groups were 86.0 and 66.9 days, respectively, for the Angus (the 19.1 days difference approaches significance), and 76.0 and 62.7 days respectively for the Shorthorn. Although progesterone treatment tended to delay ovarian activity and consequently the expression of heat after calving, it did not decrease the variability of any of the intervals studied. Treatment had no significant effect on conception rate. For 19 treated and 18 untreated Anguses bred at first heat the average conception rates were 84.2% and 83.3% respectively, and for 8 treated and 7 untreated Shorthorns were 50.0% and 71.4%, respectively.

210. STUDIES ON THE EFFECT OF INJECTION OF RABBITS WITH RABBIT EMBRYO BREI ON SUBSEQUENT PREGNANCY. A. Winter, C. Kiddy, L. E. Casida and S. H. McNutt, *University of Wisconsin.*

A study was made in rabbits to determine the effect of "immunization" with rabbit embryo brei on embryo survival in a subsequent pregnancy. Forty mature. virgin female rabbits were injected parenterally with rabbit embryo brei twice at a four-week interval. Part of the injected material had been mixed with killed bacteria (*E. coli, staphylococci*), and staphylococcal toxin, the other part with Freund adjuvant. A breeding trial failed to show a significant difference in either fertilization rate or in percentage embryo survival between the "immunized" group and a similar number of control animals. There was, in fact, a trend toward an increased embryo survival in the "immunized" group (51%) in comparison with the control group (35%). Antibodies against some component of the embryo material were detected in the sera of nearly half the "immunized" animals by means of Boyden's hemagglutination test with tannic acid treated cells. There was no clear relationship between the existence of serum antibodies and the degree of embryo survival in the "immunized" animals. Although in this experiment embryo survival was not affected by the "immunization" procedure, the interaction of maternal antibodies with fetal antigens remains a possible mechanism of infertility.

211. A TECHNIQUE OF FREEZING AND STORING CATTLE ERYTHROCYTES FOR USE IN BLOOD TYPING. W. H. Stone, W. J. Tyler and M. R. Irwin, *University of Wisconsin.*

Whole blood is warmed to 37° C. and centrifuged at 2500 rpm. for 20 minutes. The plasma is removed and replaced with 40% ethylene glycol at 37° C. made up in a 6% sodium citrate solution. After mixing, the blood is put into plastic tubes, stoppered and

stored at −20° C. To obtain erythrocytes for blood typing, the blood is thawed at room temperature or 37° C. A minimum of 4 ml. is centrifuged as described above and the supernatant discarded. The cells are resuspended in an excess of 20% ethylene glycol, centrifuged, and the procedure is repeated with respective solutions of 10%, 5% and 2% ethylene glycol. Finally, the cells are suspended in 0.9% saline. Considerable hemolysis may result, but with rare exceptions, enough intact cells can be obtained to make up a 2% suspension for use in the blood typing tests. Using this technique, we have obtained cell suspensions satisfactory for blood typing after storage for two years. Experiments on duplicate samples of cells from 10 different animals containing among them the majority of the known erythrocytic antigens of cattle blood have indicated that there was no apparent difference in the efficiency of storage between samples which were repeatedly frozen and thawed and those which were thawed only once after prolonged storage. The blood typing results of frozen and fresh samples of blood from the same individual were identical, indicating that freezing and storing over a two year period had no demonstrable effect on the cellular antigens.

212. PHENOLSULFONEPHTHALEIN CLEARANCE AS A MEASURE OF RENAL FUNCTION IN EWES. John P. Manning, Elwood F. Reber, Om P. Malhotra, Paul D. Beamer and Loyd E. Boley, *University of Illinois.*

Phenolsulfonephthalein (PSP) was administered intravenously to six ewes. Clinical observations, blood and urine studies, gross and histopathologic examination of the kidneys and liver indicated these animals were essentially normal. Urine and blood collections were made simultaneously. The standard PSP excretion test was done. The average 30-minute excretion of PSP in the urine was 56% and the average 60-minute excretion was 67%. The results of the PSP excretion tests confirmed the clinical and pathological results which had indicated the sheep had unimpaired kidney function. Plasma from the sheep was analyzed by a modification of the urine method. The average $-b_2$ value, defined as the fractional part of the volume of distribution, as represented by blood plasma, which is cleared of dye per minute on an instantaneous basis, is almost identical for cattle (0.0298) and sheep (0.0300). A comparison of calculated PSP excretion, based on plasma loss of dye, with appearance of PSP in the urine, indicated the plasma loss of dye was higher than the actual excretion. A statistical analysis of the slopes of urine excretion versus time on plasma loss of dye versus time gave a regression coefficient of $b = -0.046 \pm 0.54$. Additional investigation is needed to establish more clearly the validity of PSP disappearance from plasma as a method of measuring kidney function in the sheep.

213. FURTHER OBSERVATIONS ON BLOAT ETIOLOGY, PROPHYLAXIS AND THERAPY. R. H. Johnson, L. R. Brown, R. S. Allen, N. L. Jacobson and P. G. Homeyer, *Iowa State College.*

Cattle (initial total 41, including 6 with rumen fistulas) were divided into three groups of approximately equal bloating potential. Animals grazed alfalfa pasture daily from 7 to 10 a.m. and from 4 to 7 p.m. Each animal received 1.5 lb. of grain or grain mixed with preventive before each grazing period. Severe bloat was obtained on plots fertilized heavily with phosphate (500 lb. of 0–46–0/acre). As in the 1957 season soybean oil (SBO, 0.25 lb./feeding in a simple grain mix) gave good control for several hours. However, 0.25 lb. SBO/feeding in a mixture of equal portions of grain and ground corn cobs gave less control. Ground soybeans (natural oil content approximately 0.25 lb./feeding) failed to reduce bloat. When mixed with grain, gastric mucin (50 gm. or 100 gm./feeding) was unpalatable and did not reduce bloat; both levels seemed to increase foaming in the fistulated steers. Lard oil (100–200 ml.) administered by stomach tube gave prompt relief in severe cases of bloat if administered before animals were moribund; SBO also seems to be effective but

further work is needed for an accurate evaluation. Samples of fresh alfalfa tops were placed in nylon bags and introduced into the rumen for varying lengths of time. They were then analyzed for dry matter, ether extract, total nitrogen and ash. The "carbohydrate" fraction was determined by difference. The effects of bloat preventives, of age and turgidity of the tops, and of varying length of fermentation time upon changes in each nutrient fraction were evaluated.

214. FACTORS INFLUENCING PAROTID SALIVARY GLAND SECRETION IN SHEEP. W. E. Stewart and R. W. Dougherty, *Cornell University.*

A parotid salivary gland secretion study has been started, using new operative and electronic recording techniques. The parotid ducts were cannulated with polyethylene tubing where they cross the lateral surface of the masseter muscle. One piece of polyethylene was inserted toward the gland and another, approximately one centimeter anteriorly, toward the mouth. The polyethylene tubing was anchored in place with non-absorbable suture material, nylon, by tying several loops around the polyethylene tubing just as it emerged from the duct. The ends were then sutured into the surrounding fascia and subcutaneous muscle and then tied together. When the sheep were not being used in an experiment the ends of the polyethylene tubing were connected in a loop. Rate of flow was recorded by including in the loop an air-tight drop recorder. The electronic recorder operated with about one microamp current. Graphic recordings were obtained by connecting the stepping relays, with resistors, to the carrier preamplifiers of a Sanborn 150 6-channel recorder. Two yearling Western sheep, weighing 100 and 125 lb., fed second cutting alfalfa hay secreted 3.91 and 4.24 liters of parotid saliva in 24 hours, respectively. The secretion rate increased approximately threefold during rumination and often as much while eating compared to the continuous basal secretion rate. Rumen dry matter content influenced the secretion rate, for, after watering or after administering water to the rumen via fistula, the rate of flow was decreased.

215. SOME EFFECTS OF RATION PREPARATION ON ALTERATIONS OF THE RUMEN MUCOUS MEMBRANE. G. B. Thompson, L. D. Kintner and W. H. Pfander, *University of Missouri.*

Rumen tissue of 82 lambs from three fattening trials were examined grossly and histologically to determine the effect of ration physical form on rumen papillae development. Methods of ration preparation used included ground, pelleted, and whole grain; each fed with long, chopped, and pelleted roughages and also complete rations in meal, pellet and ground pellet forms. The feeding of completely pelleted rations containing 50% roughages compared with conventional forms of the same ration resulted in changes characterized grossly by increased length and width of papillae, increased crusting of tips and clumping of papillae with rumen contents; microscopically, by a thickened corneum with increased accumulation of visiculated keratinized cells on the outer surface layer, enlarged central core, enlarged papillary bodies extending farther into the epithelium, increased folding of the Mulpighian layer. A thickened papillary corneum was obvious in the pellet-fed lambs, and retention of degenerating nuclei and bacterial invasion of the superficial layer of desquamating vesicular horn cells were demonstrated.

216. VARIATION IN DEVELOPMENT OF RUMEN PAPILLAE IN SHEEP RECEIVING A CONSTANT DIET. John H. Sinclair, Joe D. Robbins, Fehrlin E. Tutt, Thomas D. Watkins, Jr., and H. O. Kunkel, *Texas Agricultural Experiment Station.*

Observations—gross, photographic, and microscopic—were made on the rumina, at slaughter, of 75 feed-lot lambs. Essential weight, gain, and feed-lot data were

available on 42 of these sheep. As expected, total rumen weight was significantly correlated ($r=0.608$, $P<0.01$) with average daily gain. Relative length of papillae in the ventral portion of the anterior sac was also significantly correlated with average daily gain ($r=0.583$, $P<0.01$), while estimated relative density of papillae was correlated at the 0.05 level ($r=0.31$). Since only a relatively small part of the variance in length of papillae could be explained on the basis of rumen weight ($r^2=0.179$), the partial coefficient of correlation between feed lot gain and papillary length independent of rumen weight was still highly significant ($r_{gp \cdot}r=0.423$, $P<0.01$). Papillary width appeared not to be correlated with gain ($r=0.10$). The cause-effect relationships are not clear. These data may point to a relationship of the gaining ability of the lamb to the total rumen surface area exposed to the rumen contents. In view of the reported ration effects and implied bacterial effects on papillary development (Flatt, *et al.*, J. Animal Sci. 16:1021, 1957), the variation in papillary development observed on a given diet may indicate inherent qualitative differences in bacterial population. The color or pigmentation score of the rumen mucosa varied greatly and was significantly related ($r=0.39$, $P<0.05$) to gain in the last month of the feeding period but not with the gain during the entire 118 days ($r=0.12$).

217. HYPOGLYCEMIC COMPOUNDS AS APPETITE STIMULANTS FOR BABY PIGS. J. C. Pekas, G. E. Combs, J. M. Vandepopuliere and H. D. Wallace, *University of Florida.*

Tolbutamide, a sulfonylurea compound, and insulin were administered to baby pigs (two weeks of age) to determine if experimental hypoglycemia had an effect on feed consumption. Four experiments were conducted and involved 140 animals. Tolbutamide did not produce detectable hypoglycemia as measured by the blood sampling and glucose analysis technique used, nor did it influence feed consumption, rate of gain, or liver glycogen content when administered at levels that ranged from 2.5 to 800 mg. per lb. of ration. Insulin injected intramuscularly at the rate of 0.5 and 1.0 unit per kilogram body weight produced hypoglycemia and significantly impaired rate of growth and feed consumption; however, this was thought to be a result of too large dosages of insulin as evidenced by frequent occurrence of insulin shock and coma after the injections, rather than an effect on the hunger mechanism. No evidence was obtained in this study that favors or disfavors the glucostatic theory.

218. THE EFFECT OF VARIOUS TRANQUILIZERS AND HYGROMYCIN ON FATTENING LAMBS. R. M. Jordan and H. E. Hanke, *University of Minnesota.*

Tranquilizers tested included hydroxyzine, chloropromozine and trifluoroperazine. In Trials I and II all lambs were full-fed shelled corn and alfalfa hay. Soybean oil meal was used as the carrier for the various tranquilizers and Hygromycin. In Trial I the various tranquilizers or Hygromycin fed per lamb daily resulted in the following average daily gains: Control ration, 0.63 lb.; 21.2 mg. Hygromycin, 0.63 lb.; 44.4 mg. chloropromozine, 0.64 lb.; 11.1 mg. chloropromozine, 0.65 lb.; and 4.4 mg. trifluoroperazine, 0.60 lb. Feed consumption, feed efficiency and carcass grade or yield were not affected by tranquilizers. Hygromycin supplement was not eaten readily and reduced grain consumption somewhat. In Trial II average daily gains were: Control, 0.60 lb.; 22 mg. chloropromozine per lamb daily, 0.64 lb.; 90 mg. chloropromozine, 0.62 lb.; control, 0.66 lb.; 22 mg. chloropromozine, 0.61 lb.; and 90 mg. chloropromozine, 0.58 lb. In Trials I and II total fecal egg count, leukocyte count and hemoglobin (gm. %) as well as differential white count were obtained on one-third of the lambs in each lot 2 days prior to the initiation of the trial, and at 2-week intervals thereafter. No significant difference in the hemograms or fecal egg counts were noted. In a third trial shelled corn was full-fed with three types of roughages; alfalfa hay, oat silage, or corn silage. One-half pound of hay was fed per lamb daily to those receiving

silage. Hydroxyzine was fed with each type of roughage. Average daily gains per lamb were: *Alfalfa hay*: control, 0.52 lb.; 3 mg. hydroxyzine, 0.54 lb.; *Oat silage*: control, 0.45 lb.; 6 mg. hydroxyzine, 0.48 lb.; *Corn silage*: control, 0.52 lb.; 6 mg. hydroxyzine, 0.46 lb. None of the tranquilizers regardless of levels fed had any visible depressant or tranquilizing effect on the lambs.

219. YIELD AND COMPOSITION OF MILK FROM BRAHMAN AND HEREFORD HEIFERS FED TWO LEVELS OF PROTEIN, AND THE CORRELATED CALF GROWTH. J. R. Howes, J. F. Hentges, A. C. Warnick and T. J. Cunha, *Florida Agricultural Experiment Station.*

Twelve Hereford and twelve Brahman registered heifers were allocated at random into two treatment groups, which respectively received 100% and 50% of the N.R.C. recommended protein allowances. These animals were bred to bulls of their own breed over a 90-day period. At calving and subsequent 28-day intervals the cows, after the calves had been removed, were suckled and hand milked on two successive days to determine milk yield by two alternative methods. Protein level of the ration significantly affected calf growth and milk yield, which were correlated through the first 4 months of lactation, (0.67**, 0.83**, 0.50*, 0.45*). Brahmans were significantly superior to the Herefords in milk yield, calf growth and milk protein, solids not fat, fat and total solids, an advantage which tended to disappear by the third month in all but calf growth and milk yield. The daily gains over the first 112 days for the Brahman 100% and 50% groups were 1.74 and 1.23 lb., while those for the Herefords were 1.32 and 0.97 lb., respectively. The ash data were constant throughout except in the colostrum which was slightly higher. The calculated daily dry matter and protein supply from the milk became inadequate to maintain the growth obtained between the second and third months in all experimental groups, indicating that from the third month the calves must have received much of their nutrients from grass. Some cows quadrupled the milk yield of others within the same groups, indicating a selection potential for improvement.

220. EFFECT OF A TRANQUILIZER (HYDROXYZINE) ON THE PERFORMANCE OF MILKING COWS. C. A. Lassiter, C. F. Huffman and C. W. Duncan, *Michigan State University.*

Four trials were conducted with milking cows to study the effect of feeding 2.5, 5.0, 10.0, 30.0 and 50.0 mg. per day of Tran-Q (hydroxyzine) on the performance of cows. A basal ration of liberal alfalfa hay and grain was fed in all trials except in Trial 2 when the ration consisted of hay, beet top silage, and grain. Trials 1 and 2 were double reversal in design and 10.0 mg. and 30.0 mg. of Tran-Q were fed, respectively. The periods were 12 days in length in Trial 1 and 9 in Trial 2. In Trial 3, 50.0 mg. of Tran-Q was fed in a single reversal design with the periods being 6 days in length. In Trial 4, 2.5 and 5.0 mg. of Tran-Q were fed per cow daily, using a 3x3 latin square design, with 15-day periods. Actual average daily milk production (lb./cow) by trials and level of Tran-Q were: Trial 1—control—32.0, 10.0 mg.—33.5; Trial 2—control—28.8, 30.0 mg.—27.9; Trial 3—control—29.8, 50.0 mg.—30.3; Trial 4—control—45.6, 2.5 mg.—46.1 and 5.0 mg.—45.6. In Trial 4, actual milk production averaged 44.6, 44.6 and 44.5 lb. per cow daily for the 0, 2.5 and 5.0 mg. level of Tran-Q during the last 6 days of the trial. The tranquilizer had no significant effect on milk production in any trial or at any level fed. The tranquilizer also had no significant effect on butterfat test, body weight change or feed consumption.

221. INDUCED LACTATION IN NON-PREGNANT EWES. Robert A. Bellows and J. L. Van Horn, *Montana State College.*

An experiment has been conducted in artificially inducing lactation on 11 head of dry, six- to seven-year-old ewes. Treatment I was a graded dose of estrone; Treat-

ment II, a 1:40 estradiol to progesterone ratio; Treatments III, IV, and V, respectively, were 1:40, 1:80, and 1:200 ratios of diethylstilbestrol to progesterone; Treatments VI, VII, VIII, and IX were respectively, 0.25 mg., 0.50 mg., 1.00 mg., and 5.00 mg. diethylstilbestrol; Treatment X and XI were the controls with the treatments being, respectively, 3 c.c. injection of peanut oil and udder manipulation with no injections. All injections were given intramuscularly every other day in a peanut oil carrier for 27 days. Milk-like secretion was obtained from the ewes on Treatments I, IV, VI, VII, VIII, and IX, peak daily productions being 29.9 gm., 306.8 gm., 5.5 gm., 142.4 gm., 610.5 gm., and 406.7 gm., respectively. Chemical analyses for fat, protein, lactose, ash, and total solids on all samples showed the initial secretion from the treated ewes to be lower than normal colostrum in all components. As lactation proceeded the secretion rapidly assumed the composition of normal milk, both chemically and physically. Histological measurements of alveoli and lumina revealed percent increase over the control average alveoli diameters to be 24.23, 112.37, 156.19, and 246.39 for Treatments I, IV (right and left half), and IX, respectively. Percent increases over the control average lumina diameters were 117.16, 414.18, 502.24, and 728.38 for Treatments I, IV (right and left half), and IX, respectively.

222. THE LOCATION OF MAMMAE ON THE SOW IN RELATION TO SUCKLING PREFERENCE OF PIGS. A. D. Allen and J. F. Lasley, *University of Missouri.*

A study was made of the suckling preference of pigs as measured by the number of functional nipples at weaning in inbred Landrace, Poland and Duroc sows and in Landrace x Poland crossbred sows during two consecutive lactations. Suckling pigs showed a strong preference for the anterior mammary glands. Little difference was noted in the preference of pigs for the first and second pectoral and the first abdominal mammary glands. The instances when the nipple pairs were functional at weaning, however, decreased rapidly from the second abdominal pair to the second inguinal pair where the latter were present. The larger pigs tended to suckle the anterior nipples whereas the smaller pigs suckled those which were more posterior. The number of functional mammae was significantly correlated with the number of pigs in the litter at weaning in all of the breeds and crosses. In almost all instances a preference was shown by the pigs for one side or the other of the sow's udder during the nursing period as indicated by a greater number of mammae being functional on the preferred side. This preference in two consecutive lactations was as follows: the right side in Landrace and Poland sows, the left side in the Landrace x Poland sows and in the Duroc sows the left side in the first observed lactation and no difference in the second.

223. ABILITY OF HORMONES TO EXTEND LACTATION AND PREVENT MAMMARY INVOLUTION IN PARTURIENT RATS AFTER REMOVAL OF LITTERS. Joseph Meites, *Michigan State University.*

The purpose of these experiments is to devise techniques to prolong lactation indefinitely after parturition, by administering hormones which will maintain secretory activity and prevent involution or induce growth of new mammary tissue. On the 4th day after parturition, litters from lactating rats were removed and hormones were injected daily for periods of up to 50 days. Prolactin, oxytocin or hydrocortisone each partially maintained lactation for 10 but not for 20 days, as judged by ability to express milk from the nipples, and by gross and histological examination of the mammary glands. Daily injections of all three hormones permitted lactation to continue for at least 50 days, despite a progressive decrease in the number of alveoli present in the mammary glands. Injections of any two of these hormones were somewhat more effective than any one hormone, but did not extend lactation beyond 20 days. Growth hormone, thyroxine or insulin were completely ineffective in prolonging lactation or in preventing mammary disintegration. It is apparent that the hormones used above

do not preserve indefinitely the integrity of the mammary tissue necessary for continuous lactation.

224. SOME EFFECTS OF A PLANT ESTROGEN (GENISTIN) ON REPRODUCTION IN MICE. Josph D. Shroder and Edmund Cheng, *Iowa State College.*

During a 30-day growing period 108 weanling female mice, divided into nine equal groups, were fed a semi-purified diet. Treatments were: Basal, basal +0.053, 0.107, 0.213, or 0.427 mcg. diethylstilbestrol/gm. of diet, and basal +1.33, 2.67, 5.33, or 10.67 mg. genistin/gm. of diet. Average age at time of vaginal opening was 36.5, 30.9, 30.8, 30.3, 30.5, 32.2, 31.0, 30.7, and 30.6 days, respectively. Average daily feed consumption per mouse was 3.8, 3.7, 3.6, 3.6, 3.4, 3.8, 4.0, 3.4, and 3.3 grams, respectively. Total weight gain per mouse was 7.8, 6.3, 6.1, 5.8, 5.4, 6.5, 7.1, 5.0, and 3.4 grams, respectively. In a second trial, 102 female mice of breeding age, divided into three groups of 34 mice each, received diets containing 0, 1.33, or 2.67 mg. genistin/gm. from a time beginning 2 weeks prior to breeding and continuing throughout breeding, gestation, and lactation. The percentage of females having litters was 94.1, 78.8, and 67.6, respectively, with no differences in litter size between groups. These data confirm earlier work at the North Carolina Station. Female offspring from mice receiving 0 or 2.67 mg. genistin/gm. of diet were fed these diets during a breeding cycle to determine if ingestion of genistin by the dam affected reproduction by the offspring. Results of this investigation were inconclusive.

225. INFLUENCE OF LOW LEVELS OF ORAL STILBESTROL ON OVULATION RATE AND PRENATAL LITTER SIZE IN GILTS. E. P. Young and H. S. Teague, *Ohio Agricultural Experiment Station.*

In five dry lot feeding experiments, gilts received a legume-free or an 18% alfalfa ration with or without added stilbestrol. The rations were fed for a period of 30 days before breeding was initiated. All gilts were slaughtered during gestation to permit prenatal examination of the reproductive organs. The levels of stilbestrol added per pound of ration were 0.29, 0.58 and 3.0 mcg. Following correction of the data for variation due to weight of the gilts and seasonal variation, lower ovulation rate, fewer live embryos and a lower percent of corpora lutea, represented as live embryos, were associated with the addition of these levels of stilbestrol to the legume-free ration. Levels of added stilbestrol to the legume-free ration and average number of corpora lutea and live embroys were: (none), 14.35, 11.67; (0.29 mcg.) 13.60, 10.14; (0.58 mcg.) 13.24, 9.69; and (3.0) 13.29, 10.08. The mean differences for corpora lutea were significant at $P<0.10$, while the mean differences for number of live embryos were significant at $P<0.05$. The addition of 0.29 mcg. stilbestrol per pound to the alfalfa-containing ration did not result in differences in ovulation rate or number of live embryos per gilt. These results suggest that in certain rations, the reproductive performance of gilts may be influenced by low levels of estrogenic activity, similar to the activity reported for legumes and other ration ingredients of plant origin.

226. SOURCES, LEVELS, AND METHODS OF ADMINISTRATION OF IRON FOR BABY PIGS. D. R. Zimmerman, V. W. Hays, V. C. Speer, and D. V. Catron, *Iowa State College.*

A series of five experiments was conducted to compare methods of preventing baby pig anemia. One hundred thirty-two pigs in 16 litters were used to compare an intramuscular (I.M.) injection of 100 mg. of Fe as iron-dextran with five equal oral doses of 38 mg. Fe as ferrous sulfate. Growth and hemoglobin responses at 3 and 5 wk. of age were significantly greater among the iron-dextran treated pigs. Forty litters involving 329 pigs were used to compare the following: 100 mg. Fe as iron-dextran, 10 equal doses of 40 mg. Fe as ferrous sulfate, fresh soil daily and

a negative control treatment. The pigs that received iron-dextran were heaviest at 5 wk. of age, followed by the soil, paste and negative control groups, respectively. All of the positive iron treatments resulted in satisfactory hemoglobin responses. In a third experiment involving 175 litters comparing 100 mg. Fe as iron-dextran with three iron pills (292 mg. reduced Fe per pill) weight gains were significantly greater in the iron-dextran treated pigs. In an experiment involving 12 litters under College experimental farm conditions and 24 litters under field conditions, intramuscular and intraperitoneal injections of iron-dextran were compared. The I.M. injection showed a slight but insignificant advantage in rate of growth. Hemoglobin responses were similar for both treatment groups. Another involving 40 baby pigs was conducted in an effort to determine the optimum level of iron, as iron-dextran, for both early-weaned pigs (weaned at 3 wk.) and nursing pigs until 8 wk. of age. One hundred mg. of Fe as iron-dextran was adequate for pigs weaned at 3 wk. of age, whereas 200 mg. of Fe appeared optimum for pigs nursing until 8 wk. of age.

227. THE KINETICS OF IRON METABOLISM IN THE CALF. Sam L. Hansard, Lon E. Foote and G. T. Dimopoullos, *Louisiana Agricultural Experiment Station.*

Conventional radioisotope and chemical procedures were employed in ferrokinetic studies with 21 young calves. Red cell and plasma volume, total hemoglobin and tissue iron distribution as a function of time after radioiron administration were investigated. Mean half-time of plasma iron disappearance was 2.7± 0.12 hours. Maximum Fe^{59} utilization averaged 84.3% and red blood cell incorporation rate was 0.45±0.13mg/kg/day. Red cell iron averaged 21±6mg/kg, and mean red cell life span was 47± 8 days. Radioiron concentration and turnover rate were highest in trabecular bone and in liver tissue. Radioactivity in sternum, vertebra and pelvic bones reached an initial peak at 10 to 12 hours after Fe^{59} administration. Concentration in liver reached a peak 4–6 hours after dosing and receded gradually to ¼ peak level at 24 hours. Kidney, spleen and small intestine followed similar patterns of Fe^{59} uptake, reaching peaks at 3, 5 and 12 hours, respectively. The study indicated that the initial rapid rate of Fe^{59} disappearance from plasma corresponded more closely with concentration in trabecular bone than with that of liver. $Iron^{59}$ in total organs was greatest in liver, averaging 61% of activity administered in 5 hours and decreased rapidly to 6% at 24 hours after dosing. Peak levels of 1.5% and 14% Fe^{59} in total kidneys and small intestines, respectively, occurred at 3 and 12 hours after single dose administration. Consideration of basic values for study and interpretation of iron utilization and metabolism in normal and anemic animals will be discussed.

228. STUDIES ON THE IODINE REQUIREMENT AND THYROID FUNCTION OF YOUNG PIGS. D. L. Frape, J. W. Gage, Jr., V. W. Hays, V. C. Speer, D. V. Catron, *Iowa State College.*

A series of experiments with young pigs was conducted using radio-iodine to determine the rate of thyroxine secretion by measuring the rate constant of decrease in the activity of the gland measured externally, or by replacing the natural hormone with injected L–thyroxine. The latter indicated an output of approximately 0.2 mg. L–thyroxine/100 lb. body weight/day. A low correlation between secretion rate of the young pig and feed conversion or growth rate was indicated. The effect of dietary potassium iodide from 0.055 to 4.01 ppm. on growth, feed efficiency and maximum uptake of radio-iodine was studied. Four ppm. of iodine depressed performance. The net utilization of circulating radio-iodine and the influence upon this of dietary sodium chloride was measured. Thyroid glands at birth averaged 0.2 gm. in weight and in normally fed pigs ranged from 1 to 2.5 gm. at 8 weeks of age. The influence on growth rate, feed efficiency, pulse rate, respiration rate, and bone density of the pig as a result of feeding iodinated casein at the levels of 20, 100, 120 and 150 mg./lb.

of feed in the presence or absence of corn distillers dried solubles was investigated. Higher levels of iodinated casein depressed performance. The distillers solubles appeared to reduce this depressing effect, but the response to this product was variable.

229. EFFECT OF RESERPINE ON THYROID SECRETION RATE. Richard C. Moon and Charles W. Turner, *University of Missouri.*

The tranquilizing effects of reserpine in humans are well known. Recently evidence from thyroidal I^{131} uptake studies indicates that reduction in thyroid activity results from administration of the drug. Since reserpine has been used to some extent in farm and experimental animals for purposes of tranquilization, it was thought necessary to clarify its effects upon thyroid function. Adult female rats were used which were maintained under constant environmental conditions for a period of time to stabilize thyroid activity. Following fixation of I^{131} by the thyroid, the normal rate of release was determined for several days. Reserpine (0.5 mg/kg) then was injected daily and I^{131} release rate determined for several additional days. It was found that reserpine significantly depressed I^{131} release. Individual thyroid hormone secretion rates were determined on another group of rats by replacement therapy techniques. Results indicate a lower thyroxine secretion rate is obtained when reserpine is administered. These data indicate reserpine in the dosage employed has a depressing effect upon thyroid hormone secretion and suggest thyrotropic hormone release may be depressed in some manner. It was also noted reserpine ultimately depressed appetite, with subsequent loss of body weight, from long continued daily administration. It is believed from the results of these experiments reserpine may be contraindicated for purposes of sustained tranquilization in instances where normal thyroid function is desired.

230. EFFECT OF OPTIMAL THYROXINE LEVELS UPON MILK SECRETION. Clark E. Grosvenor and Charles W. Turner, *University of Missouri.*

The thyroid hormones are known to be necessary for maintenance of milk secretion. If secreted suboptimally, though other hormones are present in adequate amounts, a reduction in milk production may result. Conversely, with optimal levels of thyroxine secretion, one or more other hormones become limiting factors in milk production. Accordingly, experiments were designed to determine the optimal level of thyroxine secretion in lactating rats and the effect of this level upon intensity of milk secretion. Individual thyroxine secretion rates (TSR) were determined in lactating and non-lactating rats of similar age and body weight and under the same environmental conditions. Lactating rats were found to have a significantly higher average TSR (2.2 ug/100 g L-thyroxine) than non-lactating rats (1.3 ug/100 g L-thyroxine). As the individual values for lactating rats ranged from 0.5 to 3.0 ug/100 g L-thyroxine, the upper level was designated as optimal and injected daily for 7 days into lactating rats. On the 14th day of lactation, the average milk yield was found to have been increased 37.7%. When combined with optimal levels of oxytocin for maximum milk removal, there resulted an increase of 63% over normal milk yields. These data are in accord with the concept that a mild hyperthyroid state is generally desirable during lactation and suggest many lactating animals secrete quantities of thyroxine insufficient for maximal milk secretion.

231. IODINE ^{131} AND BASAL METABOLIC RATES AS INFLUENCED BY METHIMAZOLE ADMINISTRATION. Arthur P. Raun, Edmund Cheng and Wise Burroughs, *Iowa State University.*

Studies were conducted with both cattle and sheep to determine the effects of different levels of orally administered methimazole (Tapazole) on the net daily elimination rate of I^{131} from the thyroid gland, theoretical uptake of thyroidal I^{131} and thyroid weight. Methimazole at levels of 300, 600 and 1200 mg. per day was observed to alter thyroid activity in steers on the basis of net elimination rate

of I^{131} from the thyroid gland. In this respect, methimazole was sporadically effective in altering the thyroid activity of lambs at levels ranging from 4 to 128 mg. per day. Although no effect was observed on metabolic rate in calorimentry studies, nevertheless, daily dose of methimazole administered to cattle at levels of 200 to 800 mg. and to sheep at levels of 5 to 65 mg. was observed to progressively increase the size of the thyroid gland. Longer periods of methimazole administration and the presence of certain other ingredients in the ration with methimazole caused a further increase in thyroid size. There was some enlargement of the anterior pituitary of the methimazole treated cattle. The results of biological assays indicated an increase of both growth hormone and thyrotropic hormone values in the anterior pituitary of the methimazole treated cattle.

232. RADIOACTIVE TRACER TECHNIQUE FOR ASSAYING GOITROGENIC RESIDUES IN BEEF TISSUES. Ned Raun, Edmund Cheng, Arthur Raun, Stanley Balloun and Paul Homeyer, *Iowa State College.*

Techniques used thus far in measuring small amounts of goitrogenic residues in meat tissues have lacked a high degree of precision. Recent encouraging feedlot results with cattle making use of a relatively new and highly potent goitrogen, methimazole (Tapazole), emphasize the need for methods with greater precision. A sensitive technique using thyroidal iodine-131 uptake in chicks was developed for this purpose. Forty-eight hours after goitrogen was withdrawn from the diet, thyroidal iodine-131 uptake of chicks was found to increase in proportion to the dose of goitrogen previously fed to them during a 12-day feeding period. Since any goitrogenic residue that might be present in meat would likely be small, it was necessary to add known levels of goitrogen to meat tissues from control cattle receiving no goitrogen in establishing a standard line. Similar levels were also added to the assay meat from cattle receiving goitrogen. Plotting the thyroidal I^{131} uptake in percent of total dose administered against the dose of goitrogen added to the meat ration, two straight lines were thus obtained. These lines when expressed mathematically and analyzed statistically gave a high degree of sensitivity in measuring goitrogenic residues. This technique has been employed for the assay of various beef tissues from cattle receiving 400, 600 and 800 mg. of methimazole per day for a feeding period of 79 days. It was found that there were no significant amounts of goitrogenic residue present in lean meat, fat, kidney, heart and liver tissues.

233. EFFECT OF HEAT ACCLIMATION ON PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES OF DAIRY HEIFERS TO VARIOUS TEMPERATURES (35° F.–95° F.). T. H. Kamal, H. D. Johnson, and A. C. Ragsdale, *University of Missouri.*

Two groups of nine dairy heifers reared at 50° and 80° F. for one year were exposed to rising environmental temperatures (35°, 50°, 70°, 80°, 90°, and 95° F.). Water consumption, urine volume per 24 hr., hematocrit, blood sugar, urinary total nitrogen and inorganic phosphorus per 24 hr.; plasma proteins, inorganic phosphorus, sodium, and potassium; thyroid I^{131} release rate and butanol soluble I^{131} extract were determined at each temperature level. The heat acclimated group (80° F. reared) averages are respectively: 39.64 L., 10.25 L., 41.59%, 51.45 mg.%, 86.71 gm., 0.747 gm., 7.13%, 7.55 mg.%, 348.33 mg.%, 16.24 mg.%, 8.81 k $\times 10^{-2}$ and 23.74 $\times 10^{-3}$% of dose/100 ml. plasma. These averages for the 50° F. reared group were respectively: 50.22 L., 12.95 L., 42.74%, 49.53 mg.%, 81.88 gm., 0.521 gm., 6.43%, 7.78 mg.%, 346.37 mg.%, 16.54 mg.%, 6.71 k $\times 10^{-2}$ and 19.59 $\times 10^{-3}$% of dose/100 ml. plasma. These data indicate that the heat acclimated group was higher in sodium, water retention, phosphorus clearance, total nitrogen excretion, blood glucose, plasma proteins, and thyroid activity and lower in plasma potassium and inorganic phosphorus. This may be attributed to higher adrenal and thyroid activity in the heat acclimated

group. However, both groups showed different degrees of response to the various temperature levels. At 35° F. the heat acclimated group had higher urine volume, blood sugar, plasma proteins, and urinary total nitrogen. At 95° F. the values were fairly constant while the other group showed an increase in those measurements. This indicates that the 80° F. group was more stressed at 35° F. while the contrary was true at 95° F.

234. EFFECTS OF RISING ENVIRONMENTAL TEMPERATURE (35°–90° F.) ON THYROXINE-I^{131} UTILIZATION OF YOUNG DAIRY CALVES. H. D. Johnson and T. H. Kamal, *University of Missouri.*

The effects of environmental temperature on peripheral "utilization" of thyroxine I^{131} were measured on Holstein, Brown Swiss and Jersey calves. Three calves of each breed which were approximately 2 months old were exposed to progressively rising temperatures (35°, 50°, 60°, 70°, 80°, and 90° F.)—one week at each temperature. I^{131}-labeled l-thyroxine was injected intravenously and whole blood samples (3cc) were taken approximately 24, 48, 72 and 96 hours post injection. The samples were assayed for I^{131} activity with a scintillation well counter and the disappearance of activity from the blood was used as an indication of the thyroxine I^{131} "utilization" rate (K). The data, whether expressed per kg body weight or a power of body weight to minimize body weight changes during the 6-week experimental period, show a gradual decline with rising environmental temperature. For example, average peripheral utilization rates ($K/kg \times 10^{-4}$) for Jersey, Holstein and Brown Swiss calves were respectively: 4.1, 2.2, 2.2 at 35° F.; and 3.4, 1.8 and 1.6 at 90° F. The data also show the Jersey calves to have the highest values, Holsteins intermediate and the Brown Swiss the lowest throughout the experiment. There is a striking similarity (both breed differences and temperature effects) with these "utilization rate" data and previous data on thyroid I^{131} release rate of dairy calves. This information further emphasizes the direct relationship of thyroid I^{131} release rate with thyroid function.

235. EFFECT OF ENVIRONMENTAL TEMPERATURE AND LIGHT ON THYROID ACTIVITY AND CERTAIN METABOLIC MEASURES IN SHEEP. H. E. Henderson, H. A. Henneman and E. P. Reineke, *Michigan State University.*

A total of 12 experiments each involving seven ewes was conducted in controlled temperature and light chambers to study the environmental effects on thyroid activity and other metabolic measures, as well as the relationship existing between various measures of thyroid activity. Percent uptake at zero time is not correlated with output half-time. A highly significant relationship was observed between uptake or retention of I^{131} at 3, 5 or 10 days post injection and output half-time. Retention values at 10 days post injection of I^{131} appeared to be a reliable inverse estimate of thyroid activity in ewes. Ambient temperature had a significant effect on output half-time, thyroid secretion rate and thyroid epithelial cell height but it did not affect iodine content of the thyroid as determined by chemical analysis. Significant correlations were obtained between ambient temperature and respiration (0.81), feed consumption (—0.76), body temperature (0.50), and water consumption (0.44). Ewes maintained at 12 hours of light exhibited significantly greater thyroid activity, consumed less feed and had a lower respiration rate than ewes maintained at 8 or 16 hours of light. Hours of light had no significant effect on weight gains, water intake or body temperature.

236. PREDICTING HEAT TOLERANCE FROM CALF VAPORIZATION RATES. R. G. Yeck and H. H. Kibler, *University of Missouri and USDA.*

Correlations between vaporization rates and breed heat tolerance were observed during recent studies at the Psychroenergetic Laboratory at Columbia, Missouri, con-

cerning the effects of temperature on growth and other physiological responses of beef and dairy calves. Particularly at early ages a definite relationship for each of six breeds was observed between the total vaporization rates (skin plus respiratory) of calves which were being reared at 80° F. and the rates of those which were being reared at 50° F. The ratio of 80° F. to 50° F. values correlated very well with relative heat tolerance of the breeds. The most heat tolerant breed (Brahman) had the highest ratio. The least heat tolerant (Shorthorn) had the lowest ratio. At 5 months of age the ratios were as follows: Brahman, 2.75; Santa Gertrudis, 2.33; Brown Swiss, 2.26; Jersey, 2.00; Holstein, 1.69; and Shorthorn, 1.35. Other tests in the laboratory indicate that this is the same order as the heat tolerance of the six breeds. These ratios changed very little for each breed with advancing age. The respective ratios at 12 months of age for the six foregoing breeds were as follows: 2.59; 2.30; 2.57; 2.45; 2.05; and 1.73. The changes with advancing age were greatest with the least heat tolerant animals. Measurements were made biweekly on six calves of each breed during continuous exposure to a constant temperature environment. Three of each breed were exposed to a 50° F. environment and the other three calves of a breed to an 80° F. environment.

237. RELATION OF THE RHOMBOIDEUS (HUMP) MUSCLE IN ZEBU AND EUROPEAN TYPE CATTLE. R. E. McDowell, B. T. McDaniel and N. W. Hooven, *Dairy Cattle Research Branch, USDA.*

In determining the role of the Zebu hump in heat tolerance, studies were made of the Rhomboideus muscle in Red Sindhi, Sindhi-Jersey crosses and Holsteins. In all animals dissected the Rhomboideus muscle arises along second cervical to eighth thoracic vertebra from the supia spinous ligament. The muscle consists of cervical and thoracic portions. Divisions was discernible in all animals but was most evident in the Sindhi and F_1 Sindhi-Jersey crosses. Fibers of the thoracic portion are disposed in a ventro-caudal direction and inserted to the medial surface of the scapular cartilage. Cervical fibers run longitudinally and the caudal portion joins into a strong flat tendon inserted into the lateral side of the cranio-dorsal angle of the cartilago scapulae. The anterior is attached by fasicae to the serratus ventralis. In all cases nature of the anterior attachment suggests the Rhomboideus is not of importance in raising or lowering the head. The Red Sindhi hump and the crest of the Holstein both appear to be Rhomboideus cervical in origin. The hump of the Red Sindhi was marbled with fat but did not contain sufficient fatty tissue to be regarded as a reserve food supply. The cervical portion of F_1, ¼ Jersey crosses and Holsteins were purely muscular. Hump size and location was indirectly proportional to the amount of Sindhi blood. Removal of the cervical portion (hump) did not impair movement of forelegs or affect heat tolerance. Thoracic portion does function in foreleg movement. The reason for development of the hump in the Zebu is unknown.

238. ANTIBODY RESPONSE IN BABY PIGS CHALLENGED WITH *SERRATIA MARCESCENS*. H. Brown, V. C. Speer, L. Y. Quinn, V. W. Hays, D. V. Catron, *Iowa State College.*

In order to investigate the artificially acquired active immunity in young pigs the following experiments were conducted. Twenty-four pigs were used (Experiment I) to study the age at which pigs are capable of producing antibodies to *Serratia marcescens* bacterin when they are weaned at 14 days of age and individually fed 20% protein rations with and without antibodies. Four pigs served as saline controls and eight pigs received intravenously a 1.0 ml. injection of 1.2×10^9 cells per ml. at 21 days of age and a 1.0 ml. injection of 3.0×10^8 cells per ml. at 28 days of age. Blood samples were taken at 21, 24, 35 and 39 days of age and the serum was titrated for antibodies by bacterial agglutination. A similar schedule was followed for 12 pigs receiving 10 mg. of bacitracin and 5 mg. of neomycin per lb. of ration. The antibody titer for the saline

control pigs was zero throughout the experiment while those challenged showed average antibody dilution titers of 0, 0, 1:115, 1:95 at 21, 24, 35 and 39 days of age respectively. The challenged pigs receiving the antibiotic supplemented ration showed antibody dilution titers of 0, 0, 1:180 and 1:130 at 21, 24, 35 and 39 days of age. Twenty pigs were used (Experiment II) to further study the age at which pigs produce antibodies to the same bacterin when weaned at 14 days of age and group-fed a 20% protein ration supplemented with 10 mg. bacitracin and 5 mg. neomycin per lb. The bacterin concentration in this experiment was 3.0×10^8 cells per ml. Each pig received 1.0 ml. of bacterin intraperitoneally at an average age of 16 days; 1.0 ml. intravenously at 18 days and 2.0 ml. intravenously at 23 days of age. Blood samples were taken at average ages of 16, 22, 26 and 33 days of age and the serum was titrated for antibodies by hemagglutination. The average antibody titers were 0, 1:13, 1:114 and 1:77 for the respective ages of 16, 22, 26 and 33 days of age.

239. ANTHELMINTIC ACTIVITY OF SEVERAL COMPOUNDS IN THE FEED OR WATER OF GROWING-FATTENING SWINE. F. C. Wingert, Baiba Krumins, G. V. Arnold, J. R. Sperry, W. W. Green and J. E. Foster, *University of Maryland.*

Anthelmintic activity was evaluated on the bases of the following: (1) ova counts before and after administration (all were administered when pigs were about 70 and 135 or 145 days of age, except hygromycin B which was fed continuously); (2) number of ascarids expelled and rate of expulsion following administration; (3) number of ascarids remaining in the digestive tracts at necropsy; and (4) rate and efficiency of gain. The results of the first two experiments revealed that pigs initially exposed to infested soil at 3 weeks of age became much more heavily infested than those initially exposed at 8 weeks of age. The efficacy of the various compounds in removing ascarids, when administered to groups of 10 to 12 pigs each, was as follows: cadmium anthranilate, 52.8%; piperazine carbodithioic acid (Parvex) administered in feed, 72.8% and in water, 21.4%; piperazine dihydrochloride administered in feed, 98.6% and in water, 46.3%; hygromycin B. 100%; and sodium fluoride, 78.3%. These efficacies were accurately reflected in the counts of ascarid ova conducted on fecal samples collected 5 days before, 5 days after and 12 days after treatment. Of the products investigated only sodium fluoride appeared to have had a detrimental effect upon rate and efficiency of gain. In two experiments rate of gain was depressed 5.4 and 33%, respectively; whereas feed requirement per unit of gain increased 8 and 18% respectively.

240. OCCURRENCE OF POST-PARTUM ESTRUS IN EWES. Earl L. Wiggins and Hal B. Barker, *Alabama Agricultural Experiment Station.*

Two hundred forty grade Rambouillet ewes, lambing in the period from October 10 to January 30, were checked for estrus twice daily with vasectomized rams beginning within 15 hours after parturition. Of these, 22 or 9.1% exhibited estrus between 12 and 36 hours after parturition. Similarly three of six Dorset ewes had a post-partum estrus. In the Rambouillets, the percentages of ewes exhibiting post-partum heat were 8.12% in long yearlings and 11.25% in long 2-year-olds. This difference was not significant ($P<0.7$). The long yearling ewes were in heat for an average of 2.46 checks (range 2 to 5) made at 12-hour intervals; the long 2-year-olds were in heat an average of 1.50 checks (range 1 to 2) and the 5-year-old Dorset ewes were in heat an average of 5 checks (range 3 to 9). Percentages of ewes exhibiting post-partum estrus were 16.7, 7.5, 5.3 and 4.8 for ewes lambing in October, November, December and January, respectively. These differences were not significant ($P<0.2$). Post-partum heat occurred both in ewes having access to their afterbirth and in ewes not having access to it.

241. ESTRUAL ACTIVITY IN FALL-LAMBING RAMBOUILLET EWES. Hal B. Barker and Earl L. Wiggins, *Alabama Polytechnic Institute.*

Two hundred and forty-four Rambouillet ewes were checked at approximately twelve-hour intervals with vasectomized rams for estrus from the time of parturition in 1957 to the beginning of the breeding season in 1958. Checking has been continued on approximately 100 ewes throughout the 1958 breeding season. The average interval from lambing until establishment of a regular cyclic pattern of estrual behavior was 72.8 days (range—12 to 212 days). The number of ewes lambing each month, and the average number of days from lambing to first lactation estrus were August—5 ewes, 45.9 days; October—54 ewes, 67.7 days; November—145 ewes, 72.4 days; December—19 ewes, 68.8 days; and January—21 ewes, 98.2 days. The correlation coefficient between the day of lambing within the lambing season and the interval to the first lactation estrus was highly significant ($r=0.25$; $b=0.198$ days). The average interval from lambing to first lactation estrus for 159, 2-year-old ewes was 71.8 days and for 85, 3-year-old ewes was 74.7 days. These differences were not significant. The average intervals from lambing to the beginning of cyclic estrual behavior for 8 ewes not suckling lambs was 57.7 days. Corresponding figures for 217 ewes nursing single lambs and for 19 ewes nursing twins were 72.1 and 86.6 days, respectively. These differences were not significant. The interval from lambing to the beginning of cyclic estrual activity was 61.0 days for 22 ewes exhibiting post-partum estrus. This was not significantly different from the interval of 73.9 days for 222 ewes not exhibiting post-partum estrus.

242. INFLUENCE OF THE USE OF STERILE TEASER RAMS PRIOR TO BREEDING ON SUBSEQUENT FERTILITY OF EWES. H. J. Smith, J. B. McLaren, J. A. Odom and Howard Miller, *University of Tennessee.*

Preliminary studies were made of 987 lambing records from 417 ewes for the years 1950 through 1956 to determine conception rates during various 16-day periods of the breeding season. Results showed that the maximum conception rate occurred during the 17th through the 32nd day of the breeding season when breeding rams were introduced into flocks from July 1 to August 20. However, when rams were introduced after August 8, similar conception rates were obtained for both the first and second 16-day periods. Experiments were conducted during the 1956–57 and 1957–58 seasons at three locations to investigate the influence of the use of sterile teaser rams on breeding activity and subsequent fertility of ewes. The flocks were randomly divided into control and teased groups of ewes and vasectomized teaser rams were run with the teased groups of ewes for two weeks prior to the breeding season. The beginning of the breeding season varied by locations and years but fell within the period of July 1 to August 10. A significantly ($P<.01$) larger percentage of ewes lambed during the first two weeks in teased groups of ewes at locations where the breeding season began before August 1 as compared to control groups. Average lambing dates were one to two weeks earlier in teased groups of ewes. In control groups the largest percentage of ewes lambed during the second two weeks of the season. At one location where breeding began about August 10 in both years no difference was obtained between control and teased groups. Over-all lambing percentages and percentage lamb crops were similar for both control and teased groups of ewes. It appears that the presence of the ram may stimulate breeding activity if ewes are in the transition period from the non-breeding to the breeding season.

243. EFFECT OF OXYTOCIN, PROLACTIN AND HUMAN CHORIONIC GONADOTROPHIN ON THE ESTROUS CYCLE IN THE EWE. James I. Raeside, *University of New Zealand.*

The effects of oxytocin, prolactin and human chorionic gonadotrophin (HCG) on corpora lutea of ewes during the breeding season were studied. Twenty-one New Zea-

land Romney ewes were observed for estrus, using two raddled vasectomized rams, for a period of 34 days. Estrous cycles were then synchronized by daily injections of progestrone for 10 days followed by an injection of PMS gonadotrophin. The animals were allocated to groups of five per treatment and injections commenced the second day after estrus. Prolactin (400 i.u.) and HCG (1000 i.u.) were administered daily as a subcutaneous injection in distilled water. Oxytocin was given at equal intervals as a subcutaneous injection of 10 i.u. in distilled water three times daily. Of five control ewes, two received injections of distilled water at the same time as the oxytocin group, while the remaining three were injected once daily. All animals were examined twice daily for signs of estrus. No prolongation of the estrous cycle was seen in ewes receiving oxytocin. Both prolactin and HCG were responsible for an increase in cycle length in two and three out of five animals respectively. No attempt was made to see how long estrus might be suppressed but an absence of heat for more than 30 days was seen in two ewes on prolactin treatment and one animal given HCG. All other animals in this experiment were killed within 5–6 days of the occurrence of estrus while on treatment. Histological examination of the ovaries and uterus were made subsequently.

244. ESTROGEN METABOLISM IN THE EWE. J. F. Wagner, E. P. Reineke, and H. A. Henneman, *Michigan State University.*

Estrogens were extracted from 100 ml. samples of whole blood, separated from interfering steroids, and assayed by the immature mouse uterine weight response. Recovery of 0.5 ug. estradiol added to 100 ml. of blood *in vitro* was approximately 75% with either alcohol or alcohol-ether extraction whether or not the sample was first hydrolyzed with NaOH. When 0.2–1.0 mg. of crystalline estradiol suspension was injected into ewes intravenously and 100 ml. of blood was drawn at 5 minutes, no estrogen was found by either extraction procedure. When 0.3 mg. of the Na-salt of estradiol was given intravenously, 0.462 ug.% of estradiol was found at 9 minutes in an extract obtained after hydrolysis with NaOH. Extracts obtained without hydrolysis were negative. Despite these findings it has been observed that when the suspension and solution were given at the same dose level, estrus was induced more uniformly by the former. The results indicate that the micro-crystalline suspension is removed rapidly from the blood, probably via the reticulo-endothelial system. Water soluble estrogen is apparently combined rather firmly with the blood protein. Prior to the collection of urine, two ewes were injected with 1 mg. of estradiol, one with the Na-salt and the other with the micro-crystalline suspension. Urine was collected at 15, 45, 165, and 405 minutes after the injections by means of an anchored catheter. The pattern of estrogen excretion was similar in both ewes, except that the ewe receiving the micro-crystalline suspension had twice the rate of excretion of estrogen as the ewe receiving the Na-salt of estradiol. Compared to the micro-crystalline suspension, the Na-salt of estradiol is apparently more quickly converted *in vivo* to relatively impotent excretion products that would not be detected by the assay.

245. GONADOTROPHIN CONTENT OF SHEEP PITUITARIES FOLLOWING HYPOTHALAMIC LESIONS. M. T. Clegg and W. F. Ganong, *University of California.*

Fifteen range ewes were observed daily for estrus following exposure to vasectomized rams. After at least one heat, electrolytic lesions were placed stereotaxically in varying regions of the hypothalamus of ten animals. Post-operatively five unoperated controls (Group I) and five operated controls (Group II) in which lesions were confined primarily to the mid dorsal hypothalamus and massa intermedia continued to accept the ram. In the five other ewes (Group III), the area destroyed included most of the anterior median eminence and a portion of the infundibular stalk. Estrus in these animals did not reoccur. After lesion placement, laparotomies were performed on all animals. The ovaries of both Group I and II contained mature follicles and

recently formed corpora lutea. The ovaries of all but one ewe in Group III contained only small follicles. In the one exception, a recently formed corpus luteum and medium follicles were observed. Following autopsy, weights of the pituitaries, thyroids, and adrenals were obtained. Two pituitaries from each group together with the endocrine glands were studied histologically. Assays for FSH and LH were carried out on the remaining pituitaries. There was essentially no difference in weights or histological appearance among the endocrines of all groups, except in one Group III ewe which had a very small pituitary. FSH content of the pituitaries from Group III was significantly reduced below the other groups, but LH content was not affected. These results suggest that the area limited to the anterior median eminence of the hypothalamus together with a portion of the pituitary stalk is involved in the control of pituitary FSH.

246. PITUITARY GONADOTROPHINS IN SWINE DURING THE ESTROUS CYCLE AND PREGNANCY. B. N. Day, L. L. Anderson, L. N. Hazel and R. M. Melampy, *Iowa State College.*

Pituitary glands were collected from 30 gilts slaughtered during estrus, diestrum, early proestrum and on the 25th and 85th day of pregnancy. Bioassays were conducted to determine the follicle stimulating hormone, luteinizing hormone and lactogenic hormone potencies at the different reproductive stages. The uterine weight response in immature hypophysectomized rats was considered to give an approximate measurement of the relative FSH potency. Weight increments of the accessory sex glands of immature male rats were used to evaluate the LH potency and the lactogenic hormone content was determined by the pigeon crop gland response. A statistically significant ($P<0.05$) increase in the FSH potency occurred from estrus to 10–12 days after the onset of estrus. The concentration of FSH during early proestrum was approximately equal to that observed on the 10th to 12th day of the estrous cycle but higher than the 25th day of gestation. Pituitaries obtained from gilts on the 85th day of gestation had a higher FSH potency than those representing early pregnancy.. The mean weights of the ventral prostate and seminal vesicles of the assay animals indicate the LH potency is higher in pregnant gilts than in gilts slaughtered during estrus or early proestrum. Differences among reproductive stage means were significant at the 10% level in the lactogenic hormone assay. The average lactogenic hormone potency per unit pituitary weight was lowest on the 2nd day of estrus and highest at the 85th day of pregnancy of the five reproductive stages studied.

247. PROGESTERONE-INDUCED REGRESSION OF CORPORA LUTEA IN PREGNANT AND CYCLING GILTS. P. H. Sammelwitz and A. V. Nalbandov, *University of Illinois.*

The effect of the administration of progesterone on corpora lutea (C.L.) development was tested in pregnant and normally cycling gilts. Levels of progesterone which previously had been shown to be sufficient to cause complete regression of C. L. in swine at 25th-30th day of gestation, were injected daily into pregnant gilts for 5, 10 and 20 days and into cycling gilts for 3–4, 7–8 and 9–10 days. All injections were intra-muscular and began the day following the first observed heat, at which time one group of animals was artificially inseminated. Examination at autopsy occurred approximately 24 hours after the last injection. The 35 pregnant gilts were divided so that they received either no treatment, 400 mg. of progesterone alone, or in combination with 25 or 50 mg. of prolactin. The 29 non-bred gilts were distributed into control and progesterone treated groups. The ovaries of animals examined at 5 and 10 days after breeding were indistinguishable from each other regardless of treatment, while the ovaries of progesterone treated gilts examined at the 20th day were significantly lighter in weight than those of the controls (due to C.L. regression). Prolactin failed to counteract the effects of progesterone. These findings indicate that exogenous

progesterone does not prevent the formation of C.L. but does cause subsequent regression of luteal tissue. The weight of the C.L. in progesterone treated, unbred gilts was not significantly different from that of the controls at the various stages of the estrus cycle examined. It would thus appear that progesterone does not significantly alter normal luteal development or regression in cycling gilts.

248. INFLUENCE OF HYSTERECTOMY AND EXOGENOUS PROGESTERONE ON THE SIZE AND PROGESTERONE CONTENT OF THE CORPORA LUTEA IN GILTS. H. G. Spies, D. R. Zimmerman, H. L. Self and L. E. Casida, *University of Wisconsin.*

Four gilts (three open and one bred) were hysterectomized 7 days after the beginning of heat. The corpora lutea were marked with India ink. None of the gilts exhibited estrus before slaughter at 32, 71, 72, and 119 days post-heat. The average individual corpus luteum weight and progesterone concentration of the corpora lutea for the four gilts were 484 mg., 57 ug.; 486 mg., 79 ug.; 305 mg. (not determined); and 414 mg. 12 ug., respectively. Thus hysterectomy causes retention of the corpora lutea for prolonged intervals. An experiment involving 32 market gilts was designed to study the effect of exogenous progesterone and hysterectomy on the maintenance of the corpora lutea. All animals were bred on the first day of estrus (day-O); hysterectomy was performed on day-7 and slaughter was on day-25. Progesterone was injected subcutaneously daily from day-10 to slaughter at the rate of 1 mg. per lb. body weight per day. Four groups of gilts were involved: pregnant, pregnant+progesterone, hysterectomized, and hysterectomized+progesterone. The average individual corpus luteum weights and progesterone concentrations of the corpora lutea from the four respective groups were 419 mg., 34 ug.; 197 mg., 19 ug.; 421 mg., 42 ug.; and 181 mg., 26 ug. Progesterone treatment reduced the corpora lutea weight ($P<.01$). There was no significant effect of hysterectomy on corpus luteum weight, nor did hysterectomy or progesterone affect the average progesterone concentration significantly. The regressions of progesterone concentration on average individual corpus luteum weight were —.123, 0.180, —.114 and 0.172 within the respective groups. These regressions were heterogenous indicating progesterone treatment affected the linear relationship of these two variables.

249. EFFECT OF ESTROGEN AND PROGESTRONE ON EARLY EMBRYONIC MORTALITY IN OVARIECTOMIZED GILTS. L. L. Anderson, B. N. Day, M. A. Emmerson, L. N. Hazel and R. M. Melampy, *Iowa State College.*

Evaluation of early embryonic mortality was determined in 42 intact gilts. Three groups of gilts were slaughtered at various stages of pregnancy: Group I, 1–2 days after estrus; Group II, 25 days gestation; Group III, 40 days gestation. Embryonic mortality was expressed as the percentage of corpora lutea represented by living embryos on the day of slaughter. A high fertilization rate (100% of the ova cleaved) was observed in Group I. The average embryonic mortality rate for Group II and III was 33 and 38%, respectively. The effect of progesterone and estrogen, administered intramuscularly in sesame oil, on embryonic survival was evaluated in pregnant gilts ovariectomized on the 15th day after mating and slaughtered on the 25th day of gestation. Bilaterally ovariectomized gilts given sterile sesame oil failed to maintain pregnancy. Thirty-four ovariectomized gilts were injected with various levels of progesterone and estradiol benzoate during the 10-day period. Ovariectomized gilts given estradiol benzoate alone did not maintain pregnancy and progesterone alone was not as effective in producing optimum intra-uterine conditions as a combination of progesterone and estradiol benzoate. A level of 100 mg. of progesterone and 50 mcg. of estradiol benzoate (ratio 2000:1) per 100 lb. of body weight gave greatest increase in living embryos. Thirteen of 17 ovariectomized gilts receiving this level were preg-

nant at the 25th day of gestation. The average embryonic mortality of these 13 gilts was 21.6% or 11.4% less than 15 intact gilts slaughtered at the same stage of pregnancy.

250. SYNCHRONIZATION OF ESTRUS AND OVULATION IN SWINE. B. N. Day, L. L. Anderson, L. N. Hazel and R. M. Melampy, *Iowa State College.*

Fourteen gilts were given a single intramuscular injection of a follicle stimulating hormone preparation (Armour's Pituitary Gonadotropin) to determine the time interval from the day of treatment to the subsequent estrus produced by endogenous hormones. The FSH was administered at levels of 20, 30 and 40 Armour Units per gilt. Six of the gilts showed estrus 18 to 21 days after the FSH injection. The calculated time interval from the day of the treatment to the next naturally occurring estrus in each of the six gilts was 4 to 13 days. Ninety percent of the ova recovered from these gilts 1–2 days after estrus were fertilized as indicated by cleavage stages of two or more blastomeres. The remaining gilts in this group showed no response or an extended estrous cycle, following the hormonal treatment. In a subsequent investigation, eleven gilts were given a single injection of FSH during the luteal phase of the estrous cycle and slaughtered 5 to 12 days later to study the conditions causing the extended cycle. Examination of the ovaries in these gilts revealed normal corpora lutea formed from induced ovulations, corpora albicantia and incompletely formed corpora lutea. These undeveloped corpora lutea resembled corpora hemorrhagica in gross appearance even though sufficient time had elapsed for luteal tissue formation. An injection of a luteinizing hormone preparation 24 hours after the FSH treatment did not reduce the frequency of these abnormal corpora lutea in the treated gilts.

251. PHYSIOLOGICAL EFFECTS OF TESTOSTERONE PROPIONATE ON THE DEVELOPMENT OF SEXUALLY IMMATURE HEIFERS. R. O. Berry, A. M. Sorensen, Jr. and G. T. King, *Texas A & M College.*

Two age groups of 12 heifers each were implanted with 0, 100, 1,000 and 10,000 mg. of testosterone propionate. One group was implanted at 1 week of age and the other at 6 months of age. One ovary was removed from one animal in each group at one month and at 3 months after implantation and all animals were slaughtered at 6 months after implantation. The 10,000 mg. level suppressed follicle development in the ovaries throughout the six-month period. All levels depressed follicle development for the first 30 days but animals on the 100 and 1,000 mg. levels resumed follicular growth before slaughter. Only the 10,000 mg. level suppressed uterine development. There was a marked increase in the size of the clitoris with increase in the dosage. There was no significant difference in rate of gain or in the carcass grades in the various groups. The most noticeable difference in carcass values was a marked decrease in the percentage of carcass fat. The shear-force (measure of tenderness) of the meat in the six-month-old heifers increased with each increase in androgen level but the meat from the calves did not follow this pattern. Assay trials for residual hormone in the meat from the heifers on the 10,000 mg. level gave no response in chick comb growth.

252. ANTERIOR PITUITARY-LIKE HORMONE ACTIVITY IN THE BLOOD OF YOUNG AND MATURE BULLS. J. E. Nellor, *Michigan State University.*

Blood samples were collected from three young (15–20 months) and four mature (4–10 years) dairy bulls. Plasma samples (100–500 cc) were fractionated by Cohn's cold ethanol method 6 (J. Amer. Chem. Soc. 68:459, 1946) into Fractions II+IIIw, III-O and IV-I. These fractions were biologically assayed in hypophysectomized female rats for FSH, ICSH, TSH, ACTH and growth promoting activity. Growth promoting activity was assayed in as little as 30–50 cc. of plasma. In young bulls the activity

was equivalent to 98–121 micrograms of purified bovine growth hormone per 100 cc. of plasma, at least a tenfold increase over that found in mature bulls (4–8 micrograms/100 cc. of plasma). TSH activity was detectible in 50–70 cc. of plasma, ranging from 7.15-16.5 I.U. per 100 cc. of plasma in mature bulls and averaging 13 I.U. per 100 cc. of plasma in young bulls. ACTH activity was assayed from as little as 30 cc. of plasma. The highest activity was found in Fraction IV-I although it was detected in all fractions studied. Follicle stimulating activity was assayed in 70 cc. of plasma in Fractions II+IIIw in two of the mature bulls. Interstitial cell stimulating activity was detected in Fractions II+IIIw and III-O from 60 cc. of plasma. Follicle-stimulating activity was detected in samples containing no interstitial cell stimulating activity. Interstitial cell stimulating activity was detected in samples containing no follicle stimulating activity.

253. PROGESTERONE CONTENT OF BOVINE REPRODUCTIVE ORGANS AND BLOOD DURING PREGNANCY. R. M. Melampy and J. M. Rakes, *Iowa State College.*

A chemical study has been made of the progesterone concentration of corpus luteum, residual ovarian tissue, placenta, allantoic and amniotic fluids and blood of 59 cows during pregnancy. During the first 49 days of gestation the average progesterone concentration (mcg. per gm.) was 2.3 for luteal tissue, 1.1 for residual ovarian tissue, 0.08 for placenta, 0.06 for allantoic fluid and 0.02 for amniotic fluid. During the interval between 90–129 days the concentration was 5.0 for luteal tissue, 2.7 for residual ovarian tissue, 0.16 for placenta, 0.07 for allantoic fluid, 0.04 for amniotic fluid and 1.7 adrenal gland. During the final 30 days of pregnancy the concentration was 1.1 for luteal tissue, 0.08 for residual ovarian tissue, 0.03 for placenta, 0.04 for allantoic fluid, 0.02 for amniotic fluid and 0.7 for adrenal gland. The pregesterone contents of the corpus luteum and of the residual ovarian tissue were greatest during the period between 90–129 days of gestation. The placental content was at a maximum during the interval between 170–209 days. The largest amount of hormone was present in the allantoic fluid between 170–209 days and in the amniotic fluid between 210–249 days. The progesterone content of the adrenal gland reached a maximum during the period between 170-209 days of pregnancy. The progesterone concentration in whole blood ranged from 0.9 mcg. per 100 ml. during early pregnancy to 4.0 mcg. at about the eighth month of gestation.

254. GROWTH PROMOTING SUBSTANCES IN THE BLOOD OF MATURE COWS. K. H. Felch and J. E. Nellor, *Michigan State University.*

Blood samples were drawn from the external jugular vein of mature Holstein cows into oxalated receptacles. The red cells were removed by centrifugation and the plasma (20–100 cc.) was fractionated according to Cohn's cold ethanol Method 6 (J. Amer. Chem. Soc. 68:459, 1946). Fraction II+III was biologically assayed in hypophysectomized female rats for anterior pituitary hormone activity. The injection of Fraction II+III resulted in the death of the assay animals before the end of the three-day treatment period. The toxic action of the sample was accompanied by extreme enlargement of the uterus although ovarian stimulation was not evident. Routine ether extraction of the samples, prior to their suspension in physiological saline, removed the toxic substances. Growth promoting activity, determined by the stimulation of epiphyseal cartilage growth in the assay animals, was detectible in Fraction II+III from a minimal of 50 cc. of original plasma in the eight cows studied. The range of growth promoting activity encountered, while recognizing the limited fraction of whole blood assayed, was equivalent to 20–80 micrograms of purified bovine growth hormone per 100 cc. of plasma. Follicle stimulating, interstitial cell stimulating and thyroid stimulating activity were not detected in the fraction assayed.

255. INFLUENCE OF OPTIMAL HORMONE LEVELS UPON INTENSITY OF MILK SECRETION. Charles W. Turner and Clark E. Grosvenor, *Missouri Agricultural Experiment Station.*

The theory has been suggested that high levels of milk production in cattle are dependent upon the inheritance of optimal secretion of the various hormones influencing mammary gland growth, intensity of milk secretion and milk removal. While some evidence has been presented in regard to the role of thyroxine and growth hormone in the lactation process in cattle, evidence for other hormones is more difficult to obtain. Currently, in a single strain of rats (Sprague-Dawley-Rolfsmeyer) studies are in progress to show the normal variation in the extent of mammary gland growth during pregnancy and the variation in growth when optimal amounts of estrogen and progesterone are given. The influence of optimal amounts of various hormones alone and in conjunction with the milk "let-down" hormone (oxytocin) upon the intensity of lactation suggests that each hormone, if not secreted in optimal amounts, may limit milk production. Data indicate 50% additional milk with greater uniformity among individual values may be obtained when optimal levels of oxytocin are administered. Injection of optimal quantities of thyroxine or growth hormone (GH) for several days resulted in increases in milk yield of 37% and 42%, respectively. When combined with oxytocin, further increases resulted (63% and 61%, respectively). A combination of GH, thyroxine and oxytocin evoked a very high average yield, representing a 73% increase with further reduction among individual values.

256. RELATIONSHIP OF THYROXINE SECRETION RATE VERSUS GROWTH RATE. B. N. Premachandra, G. W. Pipes and C. W. Turner, *University of Missouri.*

In a previous publication (Poultry Sci. 37:399, 1958) marked differences in thyroxine secretion rates of two strains of New Hampshire chickens selected for several generations on the basis of high and low response to thiouracil administration was reported. The high and the low strains were perpetuated in order to study individual thyroxine secretion rate, to determine if further variation in the strains could be brought about by employing thyroxine secretion rate as a selection index and, finally, to determine the mode of inheritance of thyroxine secretion rate by suitable crosses. A study of the growth rate in the two strains revealed a slightly faster rate in the high thyroxine secretion rate strain and also the body weight at maturity was greater. The differences were not significant statistically, however. Preliminary investigations showed that the strain evolved by crossing high thyroxine secretion rate males with high thyroxine hens excelled the strain evolved by crossing with low thyroxine secretion rate males and hens both in the rate of growth and body weight at maturity. The thyroxine secretion rate of the progenies of crossings high $\times$ high and low $\times$ low will be presented as well as evidence for seasonal variation in thyroxine secretion rates in chickens.

257. CAUSES OF VARIATION IN CONCEPTION RATE AND PREGNANCY LOSS IN HOLSTEIN HEIFERS. A. C. Menge, S. E. Mares, W. J. Tyler and L. E. Casida, *University of Wisconsin.*

Conception at first service and early loss of pregnancy up to 151 days post insemination were studied in six sire-lines including 181 heifers. Evidence of conception was the presence of palpable embryonic membranes in the uterus 35–41 days after breeding. The heifers were bred at the first estrus after 15 months of age. A heifer could have one or more lost pregnancies. The sire-line of the heifer and the system of mating of the potential embryo had non-significant effects on both conception and pregnancy loss. The interaction of the heifer's sire-line with her potential embryo's

system of mating affected conception at first service ($P<.05$). The differences in percent conception between the high and low lines within the embryo's system of mating were 38.5 for the outbreds, 17.4 for the linecrosses and 73.3 for the inbreds from inbred dams. Within the various lines the differences in percent conception between the high and low systems ranged from 13.2 to 74.8. In the analysis of pregnancy loss the line and system interaction tended to have an effect on the incidence of lost pregnancies ($P<.10$). Season had a significant effect on conception at first service with fall born heifers having the highest conception rate and spring and summer born heifers the lowest while winter born animals were intermediate. Since these heifers were bred at 15 months of age the seasonal effect may be due to season of birth, season of breeding or both.

258. THE EFFECT OF SEMEN VOLUMES AND SPERM CONCENTARTIONS ON FERTILITY AND EMBRYONIC SURVIVAL IN ARTIFICIALLY INSEMINATED GILTS. F. W. Stratmand and H. L. Self, *University of Wisconsin.*

Seventy-two market weight gilts were artificially inseminated with either 10, 20, or 50 ml. of fresh semen that had been standardized so that within each of the three volumes equal numbers of gilts were inseminated with 2.5, 5.0 or 10.0 billion sperm. The percent fertility at 3 days gestation was 51.1, 42.1 and 68.0 for 10, 20 and 50 ml. respectively, ($P<0.05$) and litter size at 25 days was 0.4, 0.4 and 4.2 ($P<0.05$). There was a significant decrease in the mean number of embryos from 3 days to 25 days gestation ($P<0.01$), but there were no significant differences due to the number of sperm inseminated, nor were there significant interactions. Ova recovery rates and ovulation rates were not significantly different. These data indicate that the volume of semen inseminated is of greater importance than is the number of sperm contained therein.

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NEWS AND NOTES

The 50th Anniversary Meeting of the American Society of Animal Production will be held at the Hotel Sherman, Chicago, Friday and Saturday, November 28 and 29, 1958. A dinner will be held Friday evening, as a special event, which will take the place of the usual Saturday noon luncheon and will be followed by the annual business meeting.

The Nominating Committee of the American Society of Animal Production has proposed the following slate of candidates at the annual business meeting: For President, W. P. Garrigus; for Vice President, L. E. Harris and J. K. Loosli. The present term of office of the Secretary-Treasurer, H. H. Stonaker, expires at the end of 1959.

The Fourth Inter-American Meeting on Livestock Production in the Americas, sponsored by the Food and Agriculture Organization of the United Nations, with the cooperation of the Inter-American Institute of Agricultural Sciences, was held in Kingston, Jamaica, from July 22 to August 1, 1958. Delegations from a total of 20 countries and organizations participated in the meeting, which was concerned with recent developments in animal breeding, nutrition and management, and the control of diseases and parasites. Among those participating in the meeting were Ralph W. Phillips, Foreign Agricultural Service, and N. R. Ellis, R. E. McDowell, and James O. Grandstaff, Agricultural Research Service, USDA.

"Zeitschrift für Tierzüchtung und Züchtungsbiologie" is being reorganized. This journal was founded some 30 years ago by Prof. C. Kronacher and was edited for many years by the late Prof. Jonas Schmidt.

The scope of the journal has been enlarged, its international character is to be emphasized more and it will carry the sub-title "Journal of Animal Breeding and Genetics". Paul Parey of Spitalerstrasse 12, Hamburg 1, will continue to be the publisher. The general editor will be Prof. M. Witt of the Max Planck Institute at Mariensee near Hannover. Papers concerning hereditary defects and the genetics of laboratory mammals will be edited by Prof. Nachtsheim of the Max Planck Institute at Berlin-Dahlem. Papers on evolution or domestication and on the applied physiology of reproduction will be edited by Prof. Herre of Kiel. Papers in the field of population genetics and the inheritance of quantitative characters of larger farm animals, as well as those dealing with breeding and selection methods, will be edited by Prof. Johansson of Uppsala, Sweden. Papers may be submitted either to Prof. Witt or directly to the other editor in whose field they fall. J.L.L.

A publication entitled "Types and Breeds of African Cattle", by N. R. Joshi, E. A. McLaughlin and Ralph W. Phillips, has been issued by the Food and Agriculture Organization of the United Nations, Rome, Italy, as Agricultural Study No. 37. It contains descriptions of 33 major types of breeds, falling into eight groups. For each type of breed, information is given regarding origin, conditions in the native home of the breed, physical and functional characteristics, results of crossing and introduction into other areas (where such information is available), and sources of breeding stock and further information. The volume contains 297 pages, and 102 illustrations. It is available also in French and Spanish under the titles, "les bovins d'Afrique Types et races" and "Tipos e Razas de Bovinos Africanos," respectively. Priced at $3.00, this volume may be obtained in the U. S. A. from the Columbia University Press, International Documents Service, 2960 Broadway, New York 27, N. Y.

R. E. Patterson, Vice-Director of the Texas Agricultural Experiment Station, was named Vice-President for Agriculture of the Texas A and M College system, effective August 1. Dr. Patterson succeeds D. W. Williams, who is now in Ceylon as agricultural consultant under the technical assistance program.

Orville G. Bentley was named Dean of Agriculture and Director of the Agricultural Experiment Station of South Dakota State College effective October 1. Dr. Bentley formerly held the rank of professor at the Ohio Agricultural Experiment Station and is well known for his research contributions in large animal nutrition, especially that dealing with the metabolism of rumen microflora.

H. H. Stonaker was named Acting Head of the Animal Husbandry Department at Colorado State University in August, replacing Dr. Lloyd C. Washburn who asked to be relieved to devote full time to research and teaching. Dr. Stonaker has been a member of this department since 1942.

T. W. Dowe, formerly Associate Professor in charge of beef cattle nutrition and management, Department of Animal and Dairy Husbandry, University of Nebraska, is now Director of the Vermont Agricultural Experiment Station.

Ivan Watson, Extension Animal Husbandman at New Mexico A and M College since 1943, resigned from this position September 15, 1958. The Watsons have purchased and will operate the Sutherland Ranch in Lincoln County, New Mexico.

N. C. Fine has resigned as Head of the Animal Husbandry Department, Texas Technological College, Lubbock, Texas, to become livestock adviser of the ICA Mission in El Salvador.

Earl Ray was appointed Animal Husbandman and Geneticist at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico, effective October 1. Dr. Ray is a native of North Carolina with a MS degree from North Carolina State College and Doctorate in animal breeding from Oregon State College. He succeeds Dr. George M. Sidwell, who was transferred on July 1 to the Agricultural Research Center, Beltsville, Maryland.

James L. Krall, formerly superintendent of the Central Montana Branch Station at Moccasin, is now superintendent of the Huntley Branch Station, Huntley, Montana.

B. F. Barrentine has been appointed Head of the Chemistry Department at the Mississippi Agricultural Experiment Station.

George Hyatt, formerly Extension Specialist in charge of dairy extension work at North Carolina, was named Head of the Department of Animal Industry at North Carolina State College, effective August 1. He succeeds Dr. J. W. Pou, now director of the Arizona Extension Service.

Carl F. Sierk, Senior Animal Husbandman, State Experiment Stations Division, ARS, has been granted leave for an assignment with the International Cooperation Administration to advise with the Joint Commission on Rural Reconstruction and the Government of the Republic of China on livestock development problems on Taiwan. Dr. Sierk expects to return during the latter part of December.

Stewart H. Fowler, former Associate Professor Animal Husbandry at Washington State College, has joined the Animal Industry Department at Louisiana State University in a similar position. He will have charge of the sheep teaching and research program and will also handle work in livestock marketing. He is the author of the recently published book "The Marketing of Livestock and Meat".

Recent appointments in the Animal Husbandry Department at Mississippi State University are J. C. Dollahon who received his Ph.D. degree in June from the University of Florida and who will work in sheep and beef cattle breeding, and W. R. Backus who received his M.S. degree from the University of Tennessee and who will work in meats. R. E. Deese has returned to the department from the Delta Branch Station to take charge of some of the beef cattle research and teaching.

L. R. Arrington, Associate Professor and Associate Animal Nutritionist at the University of Florida, is spending October, November and a part of December in Ethiopia participating in a nutrition survey in that country. A team made up of nutritionists, a food technologist, physicians, dentists and biochemists will work in a number of locations in Ethiopia. The survey is sponsored by the Inter-departmental Committee on Nutrition for National Defense.

Effective July 1, 1958, Dr. H. F. Robinson became head of the newly organized Department of Genetics at North Carolina State College. The department consists of the genetics faculty previously administered in the Division of Biological Science and the quantitative geneticists in the Institute of Statistics and Department of Experimental Statistics. Dr. S. G. Stephens, previously in charge of the genetics faculty, has been awarded a Guggenheim travel grant to collect and study species in Central America and will devote full time to this phase of research in which he has already achieved international recognition.

Dr. Neil Bradley has been appointed Assistant Professor of Animal Husbandry and in charge of beef cattle research, University of Kentucky. Dr. Bradley received his B.S. and M.S. degrees from the University of Kentucky and his Ph.D. from the University of Illinois. He will replace Prof. A. R. Parsons who resigned in August to join the staff of the Fischer Packing Company of Louisville, Kentucky.

M. Rechcigl, Jr., who received his Ph.D. degree from Cornell University in June, 1958 has been awarded a postdoctoral fellowship by the National Institutes of Health. He will conduct fundamental research in the Laboratory of Biochemistry, National Cancer Institute, National Institutes of Health, Bethesda, Md.

Jay L. Lush of Iowa State College was awarded the honorary degree, Doctor of Agriculture, by the Royal Veterinary and Agricultural College of Denmark in Copenhagen, Sept. 4, during that institution's observance of its centennial.

C. L. Norton, formerly Head of the Department of Dairying at Oklahoma State University, was appointed, effective November 1, 1958, Head of the Department of Dairy Husbandry at Kansas State College. He succeeds the late F. W. Atkeson in this position.

Edmund W. Cheng, Associate Professor of Animal Husbandry, Iowa State College, was accidentally killed in a car accident October 6, while returning to Ames from Iowa City.

Robert L. Edwards recently completed a Ph.D. Degree at North Carolina State College, and has joined the Animal Husbandry Department at Clemson, South Carolina, as Assistant Animal Husbandman. Dr. Edwards will work in the field of Animal Nutrition.

The National Science Foundation has announced its eighth regular predoctoral and postdoctoral fellowship program. These fellowships are open only to citizens of the United States and are awarded solely on the basis of ability. They will be awarded in the mathematical, physical, medical, biological, and certain other sciences.

Graduate fellowships are available to those who are working toward the masters' or doctoral degrees in the first, intermediate or terminal year of graduate study. College seniors who expect to receive a baccalaureate degree during the 1958–1959 academic year are also eligible to apply. Postdoctoral fellowships are available to individuals who, as of the beginning of their fellowship tenure, have a Ph.D. in one of the fields listed above or who have had research training and experience equivalent to that represented by such a degree.

All applicants for graduate (predoctoral) awards will be required to take an examination designed to test scientific aptitude and achievement. This examination, administered by the Educational Testing Service, will be given on January 19, 1959, at designated centers throughout the United States and certain foreign countries. The annual stipends for graduate Fellows are as follows: $1800 for the first year; $2000 for the intermediate year; and $2200 for the terminal year. The annual stipend for postdoctoral Fellows is $4500. Dependency allowances will be made to married Fellows. Tuition, laboratory fees and limited travel allowances will also be provided. Further information and application materials may be obtained from the Fellowship Office, National Academy of Sciences-National Research Council, 2101 Constitution Avenue, N.W., Washington 25, D. C. The deadline for the receipt of applications for regular postdoctoral fellowships is December 22, 1958 and for graduate fellowships, January 5, 1959.

ERRATUM

In Vol. 17 No. 3 (August) p. 554, the next to last line in the third paragraph should be changed to read:

average of 7,544 million (range 2,000 million to 18.000 million) sperm

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INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, double-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts." *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest to members. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. W. D. Gallup, Department of Biochemistry, Oklahoma State University, Stillwater, Oklahoma, or to the publishers: Boyd Printing Company, 372–378 Broadway, Albany 7, New York.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. H. H. Stonaker, Department of Animal Husbandry, Colorado State University, Fort Collins, Colo., or to the publishers, Boyd Printing Company, 372–378 Broadway, Albany 7, New York.